1986 WATER QUALITY STUDY

TOWN of SALEM, NH

Prepared for the
Salem 208 Water Quality Commission
by
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A special "Thank You" goes to Mr. Clifford Sullivan and Mr. Royal Roulston for their summerlong support and encouragement.

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SUMMARY

The findings of the 1986 Water Quality Monitoring program in Salem, NH, can be looked at two ways.

The bad news our lakes are still showing signs of accelerated aging (cultural pollution) caused by an increase in the amount of nutrient pollution reaching our lakes.

The good news is this rate of deterioration may have slowed down during the last couple of years in many of our lakes.

No matter which way these two assessments may be taken, though, one should still be fully aware of the inherent uncertainties involved with making water quality adjustments, even after seven years of data.

Individually, Arlington Reservoir, Hedgehog Pond, and Captains Pond have worsened in terms of nutrient pollution since 1976, the first year of recent Salem lake data on record. Meanwhile, Shadow Lake seems to have improved a fair amount while Canobie Lake may have also improved. Millville Lake and World End Pond seem to be in the same condition as before. Not enough data has been taken from Wilson's Pond through the years to make any assessments on it.

The most serious problem confronting ALL of our lakes (except Hedgehog Pond) is nutrient loading from non-point pollution sources. The evidence behind this is the depletion of oxygen that occurs below the thermocline (the middle layer of water which separates the warm surface water from the cold bottom water) during the summer. This happens as a result of an unnaturally premature supply of nutrients in the lake which encourages prematurely increased biologic productivity. This life ultimately dies, and then the process of decomposition uses up the very limited supply of oxygen.

Still more evidence of this accelerated aging is the gradual increase in total alkalinity, pH, and specific conductivity since 1976, all of which also suggests nutrient loading.

These non-point pollution sources are generally acknowledged to come from malfunctioning septic systems. Yet more of these pollution sources undoubtably come from greater storm water runoff over expanded impervious land surfaces and from backyard fertilization. If these non-point sources are not stopped, our lakes will become choked with nuisance aquatic plants and sediments in a matter of decades instead of the more normal centuries.

The single pond which escapes this problem is Hedgehog Pond, but it has its own special concern. Hedgehog is at risk of becoming contaminated from acid rain and snowfall. If this acidification continues, Hedgehog may be subjected to additional acid-induced health hazards. An example of this may be the possibility of acidic water reacting with the mineral lake bottom and releasing toxic concentrations of trace metals from the substrate. Such a situation would be undesireable at a public swimming beach. Research is still going on in this field.

Of the five streams exposed last year (1985) as being unsanitary, three of them showed satisfactory improvement. One improved to borderline satisfaction, while the fifth stream site could not be sampled due to upstream construction which caused low flows and heavy siltation.

One other stream site at Cowbell Corner should be carefully monitored next year due to fluctuating bacteria counts.

There is a strong likelihood that our streams are also befouled by malfunctioning septic systems. In addition, many of our bridges and culverts seem to be receptacles of trash. This rubbish can not only adversely effect water quality and the visual appeal of Salem, but can also pose a real danger to the safety of people fishing or canoeing the streams.

RECOMMENDATIONS in order of priority

1. The town of Salem should continue monitoring its lakes and streams on a yearly basis. Moreover, this monitoring should begin during the Springtime and conclude during the Autumn to ensure collecting a meaningful amount of data.

2. Every effort should be made to continue educating the public on wise water-use practices and issues.

3. Hedgehog Park should be selected as a site for next summer's seismic refraction and test drilling operations that will be undertaken by the USGS to obtain groundwater data.

4. The town should initiate a program of wintertime inspections of all seasonal homes along the lakeshores to be certain they haven't been converted to year-round use. This job could be performed by a sanitarian, a position currently being considered by the town.

5. The town should supply a canoe or a small boat (including a trailor) and a vehicle to improve the productivity of the monitoring program. The current lack of this equipment hinders the effectiveness of the monitoring program to the point where the monitor must have his/her own vehicle that is capable of transporting a boat. This would also serve to make the program more visible to the public.

6. The 208 Water Quality Committee should consider sponsoring

several ordinances designed to protect the water quality.

Some suggested ordinances may be:

1) All septic systems must be inspected on a 3 year basis;

2) Establish local controls of boat speed and/or outboard engine horsepower, <u>and</u> provide the means to enforce them. This would not only improve boating safety but would also lessen the rate of lake aging and improve the water quality;

3) Following the lead of Indiana, New York, and Michigan, the 208 Water Quality Committee should encourage state legislation to ban the sales of phosphorous-containing detergents in the state. Furthermore, the feeding of waterfowl should be prohibited because of the nutrients this practice contributes to the water.

7. The effects of road salting and their impact on our lakes and groundwater should be studied and alternatives should be investigated. Some suggestions may be:

1) Experimenting with different application rates, disc spreader speeds, and/or truck body tilts;

2) Experiment with the use of brine (salt water) by adding a small tank to a spreader.

INTRODUCTION

Salem's 208 Water Quality Committee was established in 1974 to prepare, adopt, and implement a water quality management plan guided by Section 208 of the 1972 Federal Water Quality Act Amendments (Public Law 92-500).

In keeping with this goal, the responsibilities of Salem's 208 Water Quality Intern were twofold:

1) to monitor the water quality of Salem lakes and streams, and;

2) to help educate the public on sound water-use techniques.

This report is a compilation of all the data collected during the 1986 monitoring season, what it all means, and recommendations to help meet the town's goal of keeping our water resources as clean and healthy as possible.

In order to most effectively manage our lakes, it is necessary to have an understanding of the physical and chemical processes that combine to make a lake what it is today. The best way to gain this understanding is to look at what happens during a given lake's natural lifetime from its birth to its death.

BIRTH

Most of the lakes in this region were born as a result of retreating glaciers 10,000-15,000 years ago leaving behind a land of rubble and gouged-out basins which quickly filled with meltwater runoff. Shortly after birth, each infant lake was characterized by crystal clear water. Its substratum was composed entirely of mineral matter - bedrock, boulders, gravel or sand. Relatively little aquatic life existed in the sparkling blue water, though, because there were such inadequate amounts of "building-block" nutrients (ie., nitrogen, potassium, phosphorous) in the water.

Even today, there are many lakes in New Hampshire that are still in varying degrees of this youthful stage, which limnologists (lake scientists) call OLIGOTROPHIC. Lake Winnipesaukee, Windham's Cobbett's Pond, and even our own little Hedgehog Pond (though it was born only 25 years ago) are appealing examples of oligotrophic lakes.

MATURITY

With time, the accumulation of nutrients eventually built up within the lake to such a degree that conditions became very favorable for both aquatic plant and animal life. These nutrients entered the lake from its entire drainage area via its tributaries, from the rain and wind, and by leaf-fall all along the shoreline. The dissolved oxygen concentration in the lake was plentiful due to aquatic photosynthetic activity in the lake and also by the interface between the atmosphere and the lake's surface area. All in all, it enjoyed a fine balance of plant and animal life. Limnologists call this vigorous condition MESOTROPHIC, and our own Canobie Lake is a fine example of such a robust lake.

DEATH

The lake, once so barren of life, is now an enriched, fertile breeding environment of aquatic plant life due to the abundance of the never-ceasing flow of nutrients pouring into the lake. By now, so much vegetation had lived, thrived, and then died in the lake that the organic debriis that settled on the lakebed has piled to a great depth. The lake is now more properly called a pond. Even the deepest spots of the pond are shallow enough that sunlight can penetrate clear down to the murky bottom, making it possible for still more plantlife to utilize the available nutrients. Soon, aquatic plants grow so profusely throughout the enriched water that nearly all the fish life is crowded out.

This phase of a lake's lifetime is called EUTROPHIC, and the lake dies when it turns into the transitional wetland. An example of a gracious eutrophic pond in Salem is World End Pond.

The whole process of a lake's aging is called EUTROPHICATION. It is a healthy and natural process that each lake must go through.

We can't declare a lake healthy simply because it is oligotrophic or condemn a lake because it is eutrophic. To do so would be akin to saying all young people are healthy and all elderly people are not. Instead, we should strive to gain some insight on a lake's natural rate of growth - a difficult concept to grasp, given a lake's apparent perpetual lifetime.

So that leads to two more questions. How fast should any given lake age? And how do we know if it's aging faster than nature intended?

NATURAL RATE OF EUTROPHICATION

To answer the first question, lakes age at varying rates. One of the largest lakes, in terms of surface area, New England ever had was named Lake Hitchcock. Geologists believe that it was born 13,000 years ago and that it stretched for well over 100 miles along what is known today as the Connecticut River Valley, but it lasted for only 2400 years. In contrast, one study done on an Alaskan lake, also born 13,000 years ago, predicts it will die

10,000 years from now.

Reasonable estimates comparing the natural eutrophication rate of any lake relative to another lake can be made based on physical and hydrological factors. We should discuss these factors in terms of our own Salem lakes so we won't make any impossible-to-reach expectations regarding water quality goals for any particular lake.

Surface area is an obvious first physical factor, and we would probably expect that the larger a lake is the slower it would fill in (or age). Based just on this one factor, we can rank our lakes with respect to its rate of aging. Starting with the largest lake (or, alternatively speaking, the slowest-to-age lake) in Salem and working down to our smallest (or, the fastest-to-age) lake, and with the appropriate acreage next to each one, we have:

Canobie Lake	:	373 acres;
Arlington Reservoir	:	266 " ;
World End Pond	:	95 " ;
Captains Pond	:	90 " ;
Millville Lake	:	54 " ;
Shadow Lake	:	35 " .

Maximum depth adds the important "missing" dimension to the real size of a lake. Again, we might expect that deep lakes would age slower than shallow ones, so long as other factors were equal. Our ranking for maximum depth, then, is as follows:

Canobie Lake	:	44.0 feet;
Arlington Reservoir	:	36.1 " ;
Shadow Lake	:	27.9 " ;
Captains Pond	:	26.9 " ;
Millville Lake	:	13.1 " ;
World End Pond	:	5.9 " .

Mean depth is the average depth of a lake and it is a more important physical parameter than maximum depth. Mean depth is the more significant parameter of a lake's overall depth, thus it is the overall distance that nutrient rich bottom water needs to travel before it reaches the surface layer. The greater the mean depth in a lake, the slower the lake should age. Thus, our ranking is:

Canobie Lake	:	19.7 feet;
Shadow Lake	:	13.5 " ;
Arlington Reservoir	:	11.5 " ;
Captains Pond	:	10.2 " ;
Millville Lake	:	4.9 " ;
World End Pond	:	4.6 " .

The ratio of watershed area divided by lake volume is a measure of the potential for nutrient enrichment from runoff sources. Studies of New Hampshire lakes have suggested a good correlation between this parameter and pollution potential, with smaller ratios corresponding to lower levels of nutrients and, thus, lower biological lake productivity and a more delayed rate of eutrophication. Our ranking for just this parameter, with the smallest numbers corresponding to slowest aging, is:

Canobie Lake	:	<2;
Shadow Lake	:	4;
Captains Pond	:	5;
World End Pond	:	6;
Arlington Reservoir	:	18;
Millville Lake	:	84.

The bottom slope is a ratio of the lake's maximum depth to the mean diameter of a lake, expressed in a percent. It measures the extent of shallow water in a lake, which is important both for the potential of mixing nutrients from the bottom sediment into the overlying water and the potential for rooted aquatic plants in a lake. This is an inverse relationship, with a higher ratio corresponding to a smaller extent of shallow water in the lake and slower lake aging. Our ranking, based only on this parameter, is:

Shadow Lake	:	2.0%;
Captains Pond	:	1.2%;
Canobie Lake	:	1.0%;

Arlington Reservoir	:	0.9% ;
Millville Lake	:	0.8% ;
World End Pond	:	0.5% ;

The <u>shoreline configuration</u> of a lake is defined as the ratio of the shoreline length divided by the circumference of a circle having an area equal to the area of the given lake. In other words, it is a measure of how "rounded" a lake is as opposed to how irregularly shaped it might be. A value of 1 corresponds to a lake that is perfectly round. As the ratio increases, there are proportionately more areas of protected bays, coves, or narrows. Thus, the smaller the ratio the less potential there is for aquatic growth and near-shore developement, and the slower the lake would age. Salem lakes rank:

Captains Pond	:	1.21;
World End Pond	:	1.32;
Shadow Lake	:	1.58;
Canobie Lake	:	1.93;
Millville Lake	:	2.35;
Arlington Reservoir	:	3.97.

Finally, the <u>water renewal time</u> is the number of years required to completely replace the water in a lake with inflowing water, assuming complete mixing and surface inflow from streams only. This parameter is important because a lake is provided with different time spans to use the available nutrients in the water before it gets flushed out. A lake with a long water renewal time has a lot of time to utilize its available nutrients for biologic production, whereas a lake with a very short time has its nutrients flushed downstream before they get a chance to utilize them. Thus, the shorter the renewal time in a lake the shorter the rate of eutrophication might occur. Our last ranking for Salem lakes based only on this parameter is:

Millville Lake : 0.02 years;
Arlington Reservoir : 0.1 " ;
Shadow Lake : 0.4 " ;
Captains Pond : 0.5 " ;
World End Pond : 2.7 " ;
Canobie Lake : 3.3 " ;

These parameters are all summarized in Table 1.

TABLE 1

PHYSICAL PARAMETERS OF SALEM LAKES*

PARAMETERS	ARLINGTON RESERVOIR	CANOBIE LAKE	CAPTAINS POND	MILLVILLE LAKE	SHADOW LAKE	WORLD END POND
Lake Area (ac)	266	373	90	54	35	95
Max Depth (ft)	36.1	44.0	26.9	13.1	27.9	3.3
Mean Depth (ft)	11.5	19.7	10.2	4.9	13.5	4.6
Watershed area / lake volume	18	< 2	5	84	4	6
Bottom slope (%)	0.9	1.0	1.2	0.8	2.0	0.5
Shoreline Configuration	3.97	1.93	1.21	2.35	1.58	1.32
Water renewal time (yr.)	0.1	3.3	0.5	0.02	0.4	2.7

* data taken from NH WSPCC, Classification and Priority Listing of New Hampshire Lakes, Vol. II, Concord, NH.

If we tallied up these natural physical and hydrological factors, we would expect the least eutrophic lake in Salem might be Canobie Lake, followed in turn by Shadow Lake, Captains Pond, Arlington Reservoir, Millville Lake and then World End Pond.

The book-end positions of Canobie and World End are probably no great surprises to people familiar to those lakes, but neither should the comparitively low rankings of Arlington Reservoir and

Millville Lake be too surprising.

Each one was resurrected back to lake-life, so to speak, by impounding streams that presumeably once flowed through wetlands. During a still earlier time, these wetlands were likely eutrophic lakes similar to what World End Pond is like today. Thus, keeping Arlington Reservoir and (especially) Millville Lake in as "youthful" a condition as possible will require an ongoing program of lake management, monitoring, and public education. Each one of these tasks is necessary to help keep both lakes from visibly aging faster than they already do.

So now the question becomes how do we know when a lake is aging faster than it should?

ACCELERATED RATE OF EUTROPHICATION

There are covert clues that suggest a too-rapid rate of aging in a lake. One particularly effective clue is to take a cross-sectional look at a lake during the summertime. If there is a change in the depth of the boundaries that separate the three major layers of water from year-to-year, we should be concerned. But first, we should know what these so-called zones are, how they occur, and what they represent.

These zones are delineated purely by the temperature of the water, and they occur because of water's unique temperature/density relationship. Water is at its heaviest when it is at 40°F. As the temperature of the water either climbs above or falls below this critical point, it also gets proportionally lighter in weight and will float on top of heavier water.

Knowing this, we should now look at what changes take place in a New England lake from season-to-season.

AUTUMN

The water at the surface, once so warm after summer's heat, gets colder. Because of these slowly dropping temperatures, the water is also getting heavier at the top so it sinks to its appropriate level governed by the water density layering of the lake. This displacement, combined with the falling temperature of the season and the water, triggers a series of constant water density adjustments within the lake until all the water is a more or less uniform (and heavy) 40°F. The water in this condition can now be easily stirred by the wind to circulate from top to bottom throughout the lake.

WINTER

The surface water keeps getting colder and soon dips below the crucial 40° F mark. As the water gets colder and freezes, it's also getting lighter in weight and floats on top of the heavier, warmer water below. The ice cover also acts as insulation to help keep the heavier, almost-freezing water below it from freezing, which would otherwise kill all the aquatic life at the bottom.

SPRING

The ice melts, the days warm up, the water eventually warms up to an equilibrium 40°F again, and the wind whips the water around the lake in a fashion very similar to what happened during the autumn.

SUMMER

The long, hot days of summer sunshine continually warms the surface water and, at the same time, it becomes lighter in weight than the underlying cooler water. The sun cannot reach down to heat the bottom water so there is an ever-widening difference of temperature between the top and the bottom. This difference results in three very apparent zones of water - a uniformly warm upper layer, a rather narrow transitional zone of rapidly dropping water temperature, and a uniformly cool bottom layer.

Figure 1 shows the water temperature at three undefined depths with respect to the change in seasons.

FIGURE 1

SEASONAL TEMPERATURE CHANGES IN LAKES WITH DEPTH

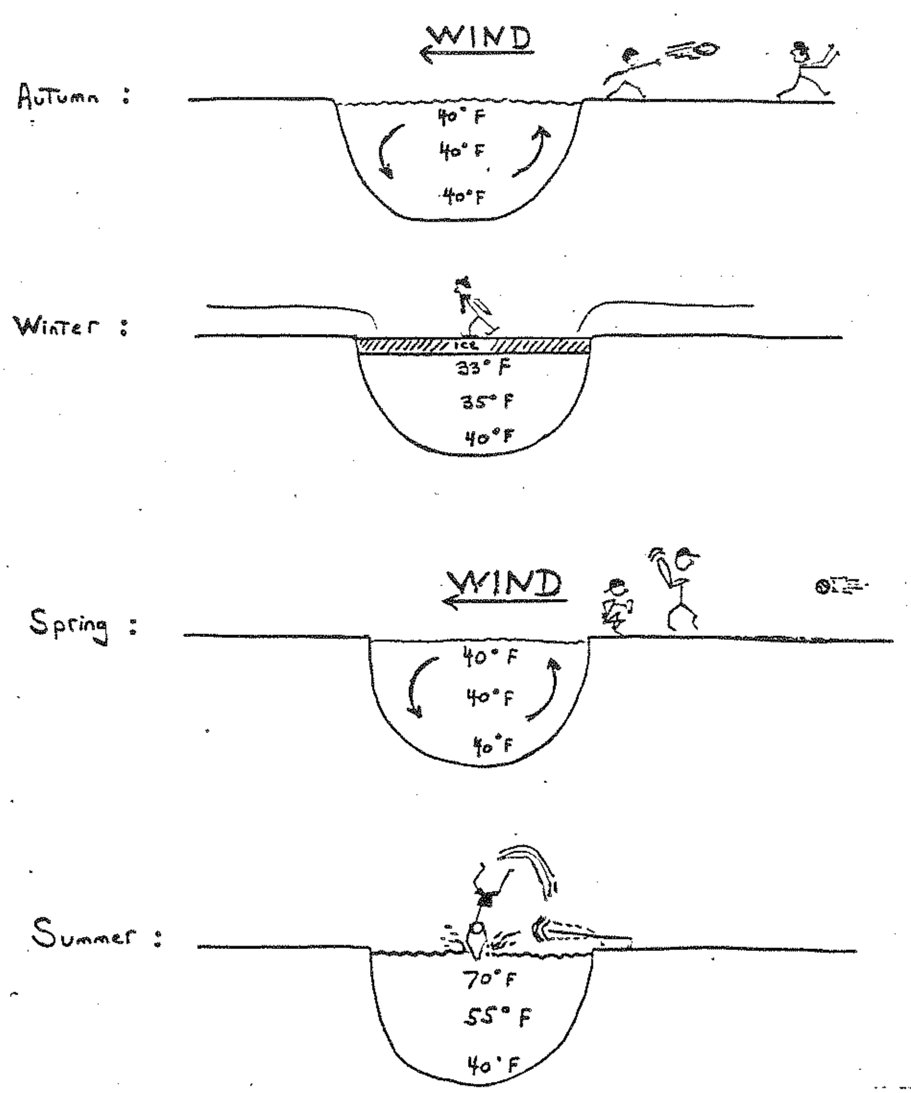


Figure 2 is a hypothetical graphic illustration that plots summertime water temperature with respect to depth. The three distinct layers delineated by temperature have been named the epilimnion, thermocline (or metalimnion), and hypolimnion.

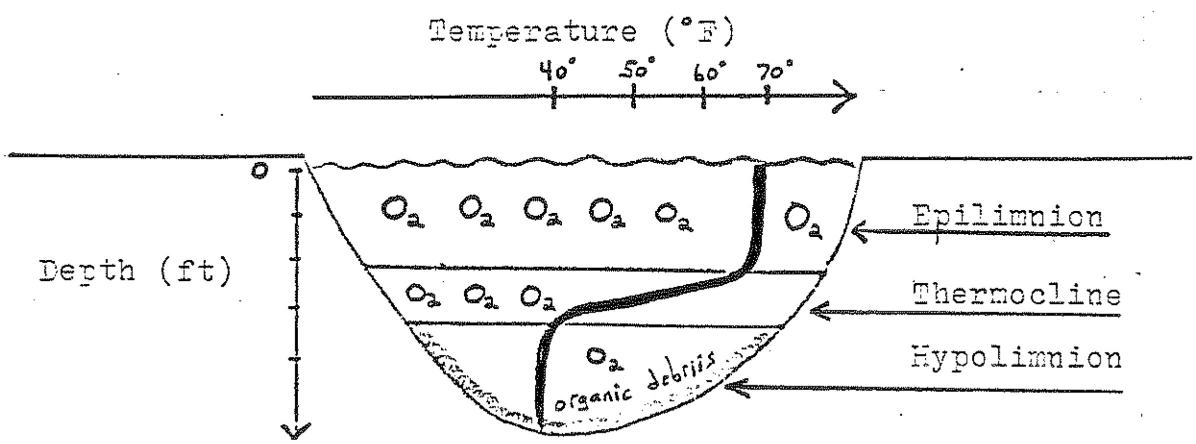
The <u>EPILIMNION</u> is defined as the region of constant temperature near the surface in a thermally stratified body of water.

The <u>THERMOCLINE</u> is the transition layer that marks the rapid temperature change at depth.

The <u>HYPOLIMNION</u> is the region of cold and constant temperature at the bottom.

<u>FIGURE 2</u>

<u>DELINEATING THE EPILIMNION, THERMOCLINE, AND HYPOLIMNION ZONES IN A LAKE and REPRESENTATIVE DISSOLVED OXYGEN CONCENTRATIONS IN EACH ZONE</u>



O_2 = Representative amounts of dissolved oxygen (mg/L)

The depth of stratification is very important in the eutrophication process. The more water there is above the thermocline, relative to the rest of the water mass, generally means the more available water there is for algal growth which increases the eutrophication rate.

This is not a hard and fast rule, however. There are so many other factors involved and so many exceptions to each one that scientists will never be able to make snap judgements concerning the rate of eutrophication. At best, short term trends over several years or more can be recognized.

Dissolved oxygen stratification is similar to thermal stratification, and is an important consequence of eutrophication. More nutrients in the water means more plant life, all of which will die sooner or later. When they do die, bacteria will decompose the debriis and may consume more oxygen during this process than the plants produced while alive. This is also depicted in figure 2 by displaying representative amounts of dissolved oxygen for each layer of water.

Again, the natural processes that contribute to eutrophication may take thousands of years before a lake evolves into a wetland. If CULTURAL EUTROPHICATION takes place, however, the time span of a lake's evolution is drastically speeded up. The eutrophication process may take only a hundred years - not a thousand - to bring the lake to the wetland stage.

CULTURAL EUTROPHICATION is defined as the enrichment of a lake or other contained water body with nutrients attributable to human activity. Some examples of these activities are malfunctioning septic systems, increasing areas of impervious land surfaces, increased fertilization, soil erosion resulting from construction projects, and even such seemingly innocuous activities like speeding around in fast boats and feeding waterfowl. Whenever these activities occur, nutrients are added to the lake system over and above what it normally receives. Each of these activities cause enough harm to our lakes that some attention should be given to each one.

Malfunctioning septic systems are generally acknowledged to be the single worst polluter of our lakes. Most of this septic pollution comes from effluent-saturated soil that surreptitiously seeps into the water as a result of overloaded systems, broken leach field pipes, or improper septic design.

Minimum space and soil requirements were established by the NH WSPCC in 1969. However, existing systems did not have to meet those requirements, Many of them are still in use and cannot possibly abide by today's minimum 75 foot distance between the leach field and the edge of the lake. Many others have exceeded their operational lifetimes which is 15 years. Still others were at one time designed for low use seasonal residences that have since been converted to year-round homes without making the appropriate year-round septic design improvements.

Another very important consequence of these malfunctioning systems is the serious hazard they pose of transmitting water-borne diseases to swimmers and other users. Studies have shown that pathogenic bacteria can be transported along distances of greater than 300 feet in saturated coarse sand or gravelly soils. Even in saturated medium-grained sand, these bacteria can travel distances greater than 75 feet.

Lakeshore developement leads to increasing impervious ground surfaces. Each road, driveway, walkway, patio, and rooftop adds more ground area that rainfall and nutrients can't infiltrate. Therefore, phosporous laden runoff is increased and it all goes directly into the lake.

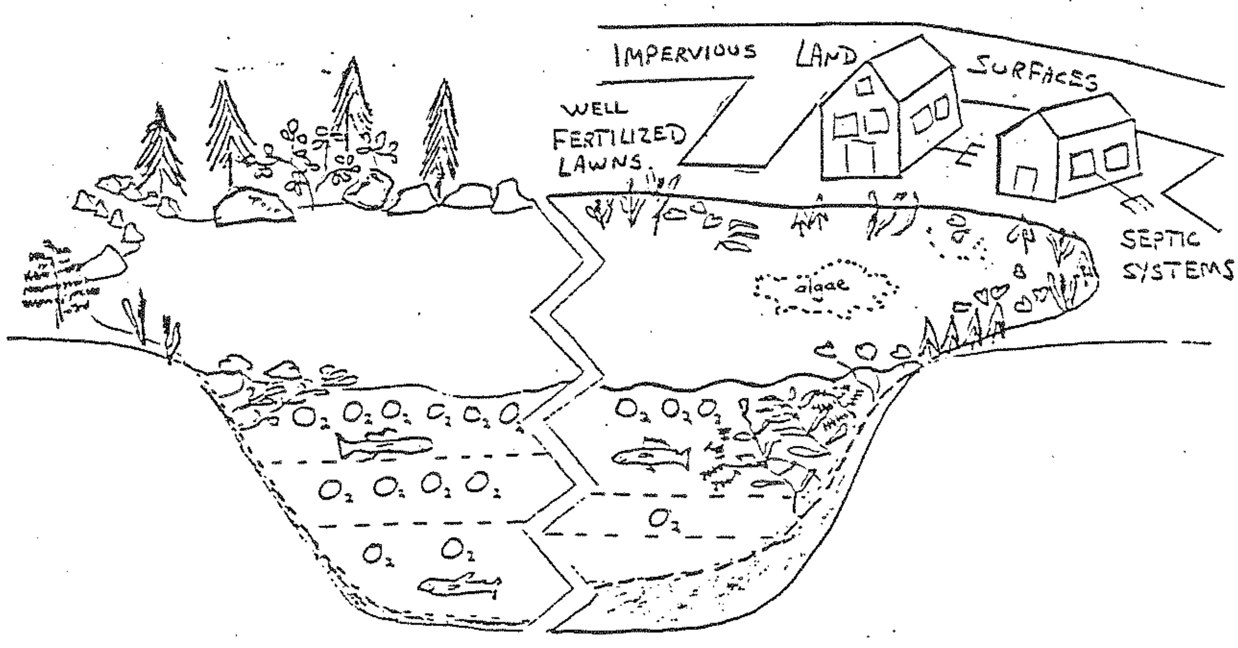
Construction disrupts the soil surface and provides maximum potential for erosion. Unless mulched and reseeded, this soil very quickly runs off into streams and lakes.

Even racing around on our wide-open lakes or feeding the wide-open beaks of ducks will contribute to faster eutrophication. High speed boats create turbulence in their wakes which churn up bottom sediments in water down to 15 feet deep. Those nutrients then recirculate through the water and get distributed around the lake again. Meanwhile, each hungry duck that is fed by some well meaning soul will deposit seven times more phosphorous into the water via its waste discharge than a human being does.

Figure 3 shows a hypothetical lake situation that compares the conditions of a lake unimpeded by human develorement with an equally aged lake that has been exposed to much cultural eutrophication.

FIGURE 3

COMPARING AN HYPOTHETICAL NATURAL LAKE WITH THE SAME LAKE IF SUBJECTED TO CULTURAL EUTROPHICATION



There is one more major pollution threat which should be addressed. This one is the ACIDIFICATION of our lakes and is characterized by decreasing biologic productivity and exceptionally clear lakes. Thus, acidification is the direct opposite of eutrophication.

It is commonly caused by air-borne pollution originating from outside the watershed. Pollutants get into the atmosphere, get blown by wind currents, and then fall back to earth with precipitation. These pollutants are most apparent in the rainfall by their abnormally low pH. Just this year (1986), the average pH of 28 rainfall events over Concord, NH, from May 1 to October 1 was 3.95 -- almost a hundred times more acidic than the pH of normal, uncontaminated rainfall (see Appendix III).

There is little that an affected community can do to stop this pollution, other than by applying temporary, quick-fix liming programs or by voting for environmentally conscientious lawmakers.

One waterbody in Salem appears to be suffering from this acidification threat - Hedgehog Pond. Considering all the attention being given to acid rain in this region, why is only one small pond in all of Salem showing the effects of it? Will our other lakes someday have the same problems that Hedgehog has today?

The answer to those questions lie with the difference between acidification and eutrophication. New Hampshire limnologists believe that failed septic systems and other non-point pollution sources more than offset the effects of acidification. Whereas acidification limits biologic productivity by lowering the pH, eutrophication tends to encourage productivity and raises the pH.

This does not simplify lake quality matters so much as it highlights the complexity of lake problems. Moreover, this report <u>DOES NOT RECOMMEND</u> the encouragement of further acidification as a cure for our lakes' eutrophic ills, or vice versa.

STATISTICAL RELEVANCE

The last topic that should be stressed is how insignificant any single year's collection of data is. Long-term trends in water quality cannot be determined with only a couple of years of data. It is even difficult to recognize short-term trends with such little data. Any differences that show up in short term comparisons could be random variations of a parameter's normal range, possibly resulting from changing weather patterns from year-to-year.

This is not intended to downplay the importance of yearly data collection. Each year's data, while unimportant all by itself, is an integral part of a continueing program of data collection. Salem started collecting data on a regular basis five years ago; merely a blink of the eye in lake time. The data that was collected back then is more important this year than it was back then, and it will increase in importance years from now, but only so long as the town continues with its monitoring program. Any data not collected during any given year will be information the town will never be able to retrieve.

The town of Salem, and everybody who lives here both now and in the future, will be the beneficiaries of this monitoring because tomorrow's intelligent lake management will be adopted only as a result of today's foresightful lake monitoring.

EXPLANATION OF PARAMETERS & METHODS

Both field and lab methods were employed to collect the chemical and biological data during the 1986 208 Water Quality Monitoring Program. Field data was collected in the morning for afternoon analyses at the recently shut down Salem Wastewater Treatment Plant lab. The monitoring was conducted every week from July through October.

FIELD PARAMETERS

Secchi Disk (m) : Water transparency is defined as how clear water is, or how far one can see through it. It was measured by gradually lowering an 8 inch diameter black and white metal disk into the water from a line marked off in half meter gradations. Just as soon as the disk disappeared from view, the depth was recorded. If it was still visible while lying on the bottom, the depth was recorded as VOB (viewed on bottom).

Factors that effect the depth of visibility include the amount of suspended sediments and abundance of algae in the water, as well as the water's natural color. The eyesight of the viewer and the brightness of the day are also factors, so this test is standardized by always lowering the secchi disk from the shady side of the boat and by using a viewing scope.

Normal ranges of secchi disk depths go from mere centimeters to exceptionally clear 30 m visibilities. However, 1.2 m (4 ft) is generally considered the lower limit for recreationally acceptable water.

Dissolved Oxygen (mg/L) : The importance of useable oxygen in water bodies is of fundamental importance for the maintenance of aquatic life and the aesthetic quality of water. This parameter was measured by recording the digital readout from an instrument called the "Hydrolab Surveyor II", which was rented from the Civil Engineering Department of the University of New Hampshire. This instrument also had several other modes, including depth, and had a 20 meter long probe.

The amount of oxygen produced in a lake depends largely on aquatic photosynthesis, but the surface area size is also a factor. This oxygen may be entirely consumed by bacteria breaking down the organic debriis during the decomposition process.

Ranges of oxygen in lakes generally go from 0-20 mg/L, Different species of aquatic organisms require different tolerance levels of oxygen, but concentrations below 3.5 mg/L is generally detrimental to fish survival.

Temperature (°C) : The temperature of water at various depths is the major criterion for determining productivity and, thus, the health of a water body. It was recorded at one meter intervals down to the thermocline, at which point additional readings were taken at half meter intervals until they once again became more constant.

This parameter was also collected by the "Hydrolab Surveyor II".

Specific Conductivity (μmhos/cm at 25 C) : This parameter is defined as the numerical expression of the ability of water to carry an electric charge. The unit deserves an explanation.

The prefix "μ" is metric for one-millionth, while a "mho" is the reciprical of electric resistance for which the standard unit is an "ohm". Hence, a "mho" is the backwards spelling of "ohm". Finally, because the temperature effects the velocity of the ions in the water sample, there must be a standard temperature.

The greater the specific conductivity, the more "stuff" there is in the water. Thus, this measurement is a useful indicator of how much inorganic (and, to a certain extent, organic) matter there is in the water. A jump in conductivity may indicate the presence of pollutants.

Conductivity measurements were collected by using either the "Hydrolab Surveyor II" or by using a portable "Hach" conductivity meter.

Typical values of this parameter for representative water types are:

acid-killed waters	:	16-24 μmhos/cm at 25 C;
oligotrophic (pristene) lakes	:	40-50 " ;
eutrophic (enriched) lakes	:	65-100 " ;
eutrophic lakes exhibiting urban runoff pollutants	:	200 " ;
sea water	:	40,000 " .

<u>Dye tests</u> : These were undertaken in an attempt to pinpoint sources of septic system failures. A dye test consisted of crushing several flourescent, water soluble tablets into a suspected malfunctioning septic system via a kitchen/bathroom sink, toilet, or man-hole cover over the septic system. If the system was in fact malfunctioning, tell-tale traces of the dye would then be visible under an ultraviolet lamp once the effluent seeped into the surface water.

LABORATORY PARAMETERS

pH : This is defined as the hydrogen ion activity of water and is mathematically determined by the logarithm of the reciprical hydrogen ion concentration. It is a very important parameter because of the effects pH has on other biological and chemical processes in water. Many organisms can tolerate only a narrow range of pH, and many chemical ions can be released into the water through the corrosive effects of pH.

This parameter was measured either in the field with the "Hydrolab Surveyor II" or in the lab with a "Backman 71 pH meter".

Natural waters generally have a range between 5.0-7.5. Water with a pH below 5.0 is very stressful to newly-hatched fish, aquatic insects, and aquatic vegetation - ultimately leading to a lake barren of any life.

Total alkalinity (mg. of $CaCO_3$/L) : This parameter is defined as the numeric capacity of water to resist (or neutralize) an acid, or the ability of water to resist a change to a decreasing pH. It is an especially important water quality parameter for New Hampshire surface waters because the granitic bedrock underlying our region is a very poor buffer to the abnormally acidic rainfall our region has been experiencing. Conversely, rising alkalinity levels in water from year-to-year may be an indicator of increasing nutrient pollution from urban sources, as reflected by the rising carbonate, bicarbonate, and hydroxide content of eutrophic water.

The potentiometric titration to an end-point pH of 4.5, as described in Standard Methods, was the lab procedure for measuring total alkalinity.

Naturally occurring alkalinity values in New Hampshire lakes range from 0-20 mg. of $CaCO_3$/L, with fully 90% of them having levels below 15 mg. of $CaCO_3$/L. Eutrophic lakes usually have high values while oligotrophic lakes, which are more prone to acidification, have low values.

Fecal coliform (colonies/100 ml) : This is defined as the measure of recent fecal pollution in a body of water. Fecal coliform bacteria grow in the intestines of warm-blooded animals which include not only humans but also waterfowl. These bacteria are also present in the soil. Coliform bacteria, while relatively harmless themselves, are always present in water containing pathogenic (disease-causing) bacteria. We test for them because they are easy to isolate, safer to handle, and because they live longer than the pathogenic bacteria.

The NH WSPCC has set a maximum limit of 240 colonies/100 ml for Class B (swimmable) water. Water with a higher count is considered unsanitary to swim in.

The membrane-filter technique, as described in Standard Methods, was the procedure used in testing for fecal coliform bacteria.

Fecal streptococcus (colonies/100 ml) : This test is defined as a supplemental test with the fecal coliform test to detect recent pollution. A fecal coliform/fecal streptococcus ratio (FC/FS) can provide useful additional data to pinpoint the origin of the fecal contamination by making use of the fact that human beings have fewer fecal streptococcus bacteria than other species of representative animals. Various FC/FS ratios, and their interpretations, are listed below:

FC/FS	Interpretation
>4.0	suggests pollution derived from human waste;
2.0-4.0	suggests a predominance of human waste in mixed pollution;
1.0-2.0	suggests a "gray" area of uncertain interpretation. Samples should be taken closer to the suspected source of pollution;
0.7-1.0	suggests a predominance of livestock or poultry waste in mixed pollution;
0.4	suggests waste from sheep;
0.2	suggests waste from cows;
0.1	suggests waste from turkeys;
0.04	suggests waste from pigs.

LAKES

Salem lakes are showing the effects of cultural eutrophication. This ongoing pollution is coming from non-point sources generally acknowledged to be malfunctioning septic systems, storm water runoff, fertilization, and other unenlightened lake environment uses.

Data was collected on eight lakes, though not much information was gathered on Canobie Lake or Wilson's Pond due to time constraints.

Table 2 compares this year's average data with that gathered since 1976. The data for some key parameters from 1976 to 1985 were averaged and are shown after the brackets next to their appropriate columns. An assessment of whether a particular parameter improved (↑) or declined (↓) this year for a given lake, relative to each one's recent average, is indicated by the arrows next to the 1986 data. Where no significant change has occurred compared to the average, no arrow was drawn.

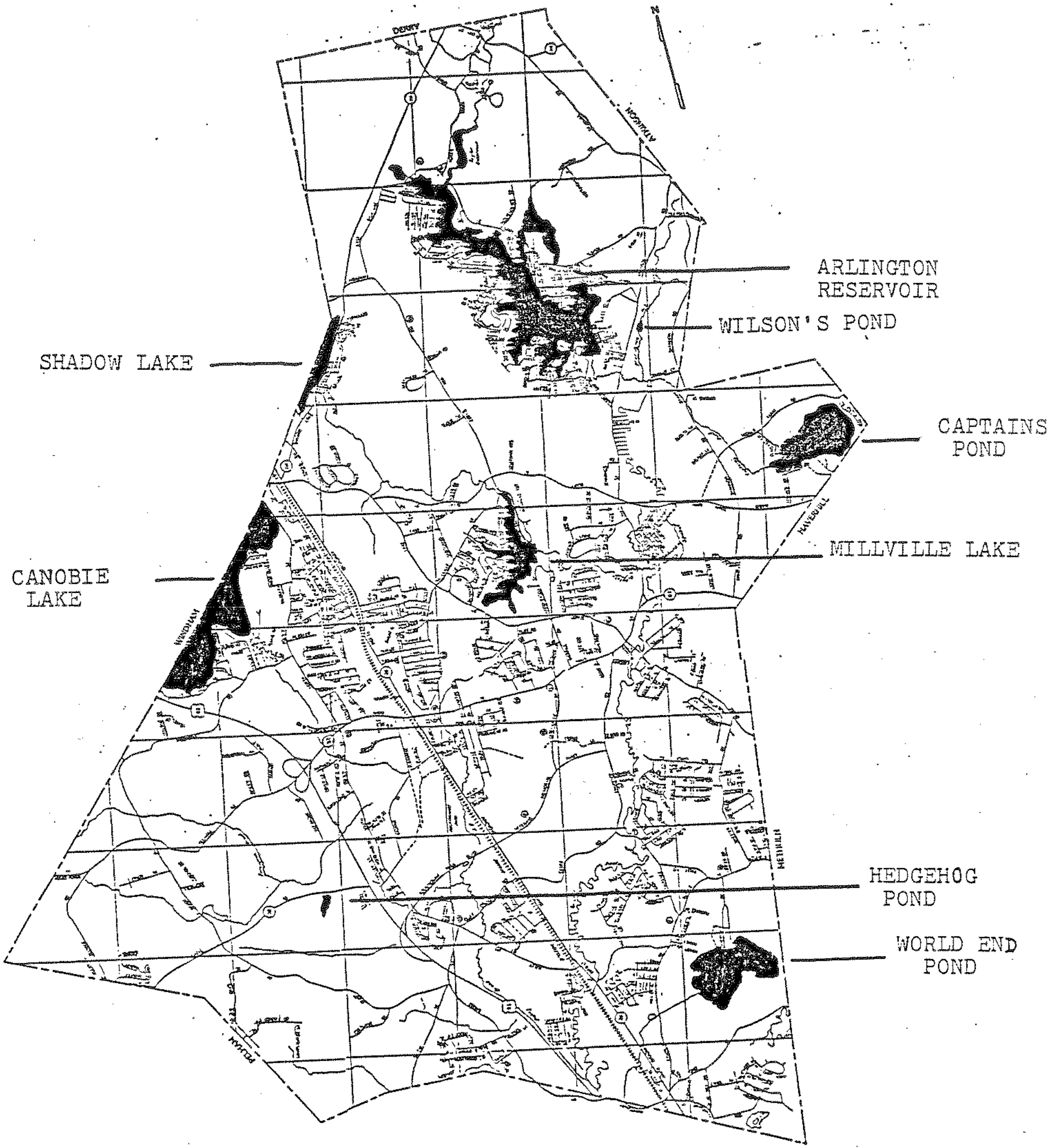
Table 3 shows the sanitary quality of the town's lakes by showing the results of their fecal coliform tests, the standard maximum allowable population of which is 240 colonies/100 ml.

Table 4 compares this year's data with 341 other New Hampshire lakes. Overall, our lakes are more eutrophic than the "typical" New Hampshire lake.

While there is nothing wrong with a lake being eutrophic, there is evidence that our lakes are more eutrophic than they should be. Immediately following the tables in this chapter will be a more detailed discussion of each Salem lake. More monitoring should be done on each one of them in the future.

FIGURE 4

LOCATION KEY : SALEM, NH, LAKES



1" : 5000'

TABLE 2

A TEN YEAR COMPARISON OF SELECTED LAKE PARAMETERS

LAKE	YEAR	Surface DO (mg/L)	Summertime Depth at which DO < 3½ mg/L (m)	Secchi Disk (m)	pH	Conductivity (µmhos/cm @ °25C)	Total Alkalinity (mg $CaCO_3$/L)
ARLINGTON	1976	-	-	4.4	6.9	81	11.5
	1981	8.2	5.6	3.5	5.99	-	12.9
	1982	6.5	4.3	3.3	6.5-6.8	-	8 -- 13
	1983	8.0	6.5 } 5.4	3.4 } 4.0	5.4-6.4	94 } 97	12.9
	1984	8.06	5.3	6.3	6.69	-	-
	1985	8.39	5.2	2.9	6.62	115	
	1986	**7.70**	**6.5**	**3.1 ↓**	**6.36**	**111 ↓**	**13.0**
CANOBIE	1976	7.2	8.0	5.0	6.9	157	9.0
	1981	7.8	7.2	6.0	6.04	-	10.5
	1982	7.1	7.9	5.3 } 6.8	6.5-7.2	-	12 -- 16.7
	1983	7.8	8.2	6.2	5.9-6.4	161 } 158	17.0
	1984	7.98	7.9	11.4	6.90	-	-
	1985	8.54	9.4	7.1	6.87	156	-
	1986	**8.49**	-	-	**6.50**	**137 ↑**	-
CAPTAINS	1976	7.5	5.0	3.2	5.0	80	2.5
	1981	-	-	2.3	5.9*	-	10*
	1982	-	-	-	-	-	-
	1983	-	-	3.3 } 3.2	-	-	-
	1984	4.20	-	4.0	-	-	-
	1985	8.11	4.2	3.3	6.76	83	-
	1986	**7.60**	**4.7**	**3.2**	**6.74 ↓**	**82**	**11 ↓**

(continued)

TABLE 2 (cont.)

A TEN YEAR COMPARISON OF SELECTED LAKE PARAMETERS

LAKE	YEAR	Surface DO (mg/L)	Summertime Depth at which DO < 3½ mg/L (m)		Secchi Disk (m)		pH	Conductivity (μmhos/cm @ 25C)		Total Alkalinity (mg CaCO₃/L)
HEDGEHOG	1976	–	–		–		–	–		–
	1981	–	–		–		–	–		–
	1982	–	–		–		–	–		–
	1983	–	–		–		–	–		–
	1984	7.2	DNS		VOB		–	–		–
	1985	8.7	DNS		VOB		5.80	–		–
	1986	12.4	DNS		VOB		5.25	39		1
MILLVILLE	1976	8.6	2.2		2.0		7.1	93		15.5
	1981	8.2	2.7		1.8		6.0	–		17.2
	1982	8.0	2.7		1.9		6.2-6.8	–		13.8 -- 20.0
	1983	8.3	–	2.4	2.0	1.9	6.6	139	144	–
	1984	–	–		–		–	–		–
	1985	6.95	1.8		1.8		6.32	200		–
	1986	7.75	2.7		2.0		6.4	147		16.0
SHADOW	1976	8.5	3.3		2.4		–	79		9.5
	1981	7.7	2.3		1.9		5.65	–		12.1
	1982	–	–	2.9	1.8	2.1	–	–	121	–
	1983	7.8	2.8		3.2		6.3-6.8	134		–
	1984	–	–		–		–	–		–
	1985	8.03	3.1		2.5		6.52	150		–
	1986	8.25	3.0		2.8		6.29	130		8.0

(continued)

TABLE 2 (cont.)

A TEN YEAR COMPARISON OF SELECTED LAKE PARAMETERS

LAKE	YEAR	Surface DO. (mg/L)	Summertime Depth at which DO $< 3\frac{1}{2}$ mg/L (m)	Secchi Disk (m)	pH	Conductivity (μmhos/cm @ 25C)	Total Alkalinity (mg $CaCO_3$/L)
WILSON'S	1984	-	-	1.5	-	-	-
	1985	8.25	1.8	1.4	6.37	150	-
	1986	-	-	-	6.59	136	-
WORLD END	1981	-	-	VOB	-	-	-
	1982	-	-	-	-	-	-
	1983	-	-	-	-	-	-
	1984	6.4	DNS	VOB	7.1	146 } 185	33.7
	1985	8.11	DNS	VOB	7.02	225	-
	1986	6.80	DNS	VOB	6.52	173	36

1976 data taken from Classification & Priority Listing of NH Lakes; Vol. II; NH WSPCC.
1981 -- 1983 data taken from Lake Lay Monitoring Program; Water Resource Research Center.
1984 data taken from 1984 Water Quality Study; Brody, K.
1985 data taken from 1985 Water Quality Study; Dudley, D.
* : from Winter Testing of Temperature & Several Chemical Characteristics of Five Salem, NH Area Water Bodies; Vafides, D.
VOB : Viewed On Bottom
DNS : Did Not Stratify

TABLE 3

SANITARY QUALITY OF SALEM LAKES AS DETERMINED BY FECAL COLIFORM BACTERIA POPULATIONS

Lake	Colonies of Fecal Coliform/100 ml	
	Range	Average
ARLINGTON	0 - 35	9
CAPTAINS	0 - 2	1
HEDGEHOG	0 - 72	25
MILLVILLE	10 - 61	27
SHADOW	49	49
WILSON'S	23	23
WORLD END	0	0

TABLE 4

COMPARING SALEM LAKES WITH 341 OTHER NEW HAMPSHIRE LAKES *

LAKE	pH Median	pH Range	Total Alkalinity (mg $CaCO_3$/L) Average	Total Alkalinity (mg $CaCO_3$/L) Range	Specific Conductivity (μmhos/cm @ °25C) Average	Specific Conductivity (μmhos/cm @ °25C) Range
341 NH Lakes	6.5	4.4-9.6	6.9	0-42	60.9	12.8-1221
	Average					
ARLINGTON	6.36	6.3-6.5	13		111	
CANOBIE	6.50	6.4-6.6	-		137	
CAPTAINS	6.74	6.6-6.8	11		82	
HEDGEHOG	5.25	4.9-6.5	<1		39	
MILLVILLE	6.40	6.1-7.0	16		147	
SHADOW	6.29	-	8		136	
WORLD END	6.52	6.2-6.7	36		173	

* : excerpted from Baboosic Lake Study; NH WSPCC; 1986

ARLINGTON RESERVOIR

Arlington Reservoir was sampled on July 19, August 26, and September 15. Profile dissolved oxygen and temperature data were taken at 1 meter intervals down to the lakebottom during the latter two dates.

There was evidence that this impounded lake experienced increased nutrient loading this year, therefore boosting the rate of eutrophication. There was a change in the depth of the epilimnion, thermocline, and hypolimnion this year, with their boundaries falling deeper than in previous years. The greater volume of water in the topmost epilimnion zone could lead to increased algal production.

It's possible this condition could have arisen from this year's greater precipitation, which could have been responsible for more water mixing throughout the lake. More data may and may not confirm this possibility.

As in previous years, there was a depletion of oxygen at the bottom of the lake, sharply dropping off at the 5.5 m (18 ft) depth.

The secchi disk depth also declined this year, despite the high water level of the lake. However, if the curiously high 1984 figure was discounted, this year's secchi disk reading would almost match the corrected average since 1976.

The total alkalinity (13 mg $CaCO_3$/L) was high compared to NH lakes, but it did not significantly change since 1976.

The specific conductivity seems to be climbing higher with the years, which should be of some concern. It was a high 111 μmhos/cm, which corresponds to a highly enriched eutrophic lake.

The pH ranged from 6.28 to 6.54 during the summer, which all fell within the natural range of water.

Fecal coliform counts were taken over the two deepest spots and at three other shoreline locations, plus many more at Mary Ann Beach which will be discussed more closely in the next section. All of these counts (excluding Mary Ann Beach) ranged from 0 to 35 colonies/100 ml and posed no sanitary problems.

Arlington Reservoir is a water body which tends to get eutrophic quickly due to several physical factors. Its watershed area to water volume ratio is high, so the lake naturally gets plenty of nutrients from its upstream drainage area. Also, its many small and shallow coves and irregular shape encourages the eutrophication process, all of which outweigh its short water renewal time and fairly large size inhibiting eutrophication.

MARY ANN BEACH

Mary Ann Beach was closed by order of the Board of Selectmen during their August 5 session by reason of bacterial contamination. Fecal coliform tests showed 1641 colonies/100 ml of bacteria at the time, well exceeding the NH maximum limit of 240 colonies/100 ml for Class B (swimmable) waters.

The source of this contamination came from effluent pumped into the water from 195 Shore Drive, a residence with a history of septic system failures.

The chain of events that involved the 208 Water Quality Committee with the beach began with a telephone call on Monday, July 28, from an anonymous resident who complained of sewage smells coming from the private beach. Water quality tests were performed the next day. One of these was a fecal coliform test which showed a count of 226 colonies/100 ml. This was close to the maximum limit so it warranted further investigation.

More tests were performed on Thurseday, July 31, at three locations chosen by the town's Health Officer. These tests had counts as high as 603 colonies. Still more tests on Friday, August 1, pinpointed the most severe contamination at the southern edge of the cove directly off lot #24 with 1641 colonies/100 ml. Throughout the rest of the testing period, this location consistently had the highest bacteria counts.

This location was also regularly frequented by a large flock of ducks which were fed daily by people living nearby. These ducks were erroneously thought to be the source of the bacteria problem because waterfowl can contaminate water by discharging their fecal waste material into concentrated areas over a period of time. Knowing this, a program to discourage feeding them was instituted as a visible show of remedial action to improve the quality of the water.

More fecal coliform tests were taken at the beach on a daily basis by this time. Fortunately, each round of tests showed an improvement. Nevertheless, the beach was closed on Tuesday, August 5. At the same time, the daily monitoring was stepped up to include a dye test at each home in the neighberhood.

The next day, a fecal streptococcus test was performed in an effort to determine the source of the bacteria, but it turned out unsuccessful. This test requires a companion fecal coliform test taken the same day and at the same location, and it must show 100 or more colonies/100 ml. By the time this fecal streptococcus test was run, the companion fecal coliform tests had counts below 100 colonies. Concurrent fecal coliform tests, taken the same day by the town's environmental consulting firm G. Underwood Engineers, Inc., also had similar low bacteria counts.

As a result of these encouraging reports, Mary Ann Beach was reopened on Thurseday, August 7, although the daily water monitoring and dye tests continued.

The next day, fifteen gallons of Clorox, a commercially available disinfectant, was poured throughout the beach area to kill remnant bacteria. Five days later, the coliform bacteria population was reduced to single digit figures.

A new eptic system was installed at 195 Shore Drive, and the counts remained very low for the rest of the summer.

CANOBIE LAKE

Canobie Lake was sampled only once during the summer due to time constraints. Unfortunately, the sampling day was so windy and had such strong water currents that the secchi disk depth and profile oxygen/temperature data were all questionable.

The specific conductivity was high (137 μmhos/cm @ 25°C) and may be an indicator of septic or road salting pollution. The count was lower than in previous years, though, so these potential pollution sources may be improving. Normal conductivity levels for a lake such as Canobie should be around 50 μmhos/cm.

The pH was a normal 6.50.

The town of Windham took over 30 total coliform bacteria samples on the lake because it is classified as a Class A water supply. All of these tests had acceptable results, according to the town's Health Officer.

Total coliform tests differ from fecal coliform tests. It is a mandatory test used throughout North America for potable (drinking) water whereas the fecal coliform test is performed to detect recent sanitary pollution on non-potable water bodies. The town of Salem performed total coliform tests on the water after purification and these also tested well each time.

Canobie Lake is a good example of a lake which tends to naturally inhibit eutrophication. Situated very high in its watershed, it receives proportionately little nutrients from its tributary streams, which is reflected in its very small watershed : lake volume ratio of less than two. Still more eutrophication hindering features Canobie has are its large size and its low

low shoreline configuration, which means it has few coves along its shoreline.

There's only one hydrological feature which encourages aging at Canobie Lake - its longwater renewal time of 3.3 years. This means that the water, and the nutrients in it, will have about that length of time to be utilized for biologic production before it gets flushed out of the lake via its outlet stream.

CAPTAINS POND

Surface measurements were taken at Captains Pond on August 13 while profile data was taken on September 5. These results show that Captains Pond has experienced increasing pollution that contributes to faster eutrophication.

The bottom seven feet of water were completely depleted of oxygen by late summer despite the abundance of bottom vegetation. Also, the dissolved oxygen profile showed a concavity in the epilimnion which probably resulted from decaying phytoplankton. Both of these observations are clues to nutrient loading in the lake.

This year's pH (6.74) at Captains was the highest recorded in Salem's lakes and could very well be due to the increasing alkalinity (11.0 mg $CaCO_3$/L) of recent years. Ten years ago, these counts were 5.0 and 2.5 mg $CaCO_3$/L, respectively. While they are both within normal ranges, each parameter represents a significant jump in a ten year period of time.

The transparency of the water remained about the same as last year - the secchi disk was visible at 3.2 m (10.5 ft) compared to last year's 3.3 m (10.8 ft).

The specific conductivity also remained close to last year's level - 82 μmhos/cm @ 25°C compared to last year's 83. These counts represent normal figures for a naturally eutrophic lake.

Two samples were analyzed for fecal coliform bacteria and they yielded counts of 0 and 2 colonies/100 ml. - both excellent sanitary counts.

HEDGEHOG POND

Born from a borrow pit during the construction of Interstate 93 nearly 25 years ago, Hedgehog Pond is unique among Salem water bodies. It is classified as a very new pond (oligotrophic) and is characterized by its lack of nutrients and by its clear and pristene transparency. However, its extremely small size and lack of any inlets or outlets makes it very susceptable to increasing acidity from precipitation. In addition, the area is very sandy and could possibly be susceptable to potential groundwater pollution from nearby small industry and landfill.

Hedgehog's pH and total alkalinity were the lowest recorded in Salem. The pH was 5.25, lower than last year's measure and low enough to approach the low end of naturally occurring conditions. Its total alkalinity was <1 mg $CaCO_3$/L, which puts Hedgehog in an extremely critical state of potential - if not ongoing - acidification.

Its small size and nearly non-existent buffering makes Hedgehog extremely vulnerable to low rainfall pH, especially since the average pH of this year's precipitation from May to October (see Appendix III) was 3.95 - greater than ten times the acidity Hedgehog is.

While a lowering of the pH may be looked upon favorably at a recreational swimming area since it results in attractively clear and inviting water, other health hazards must be considered. The possibility exists that acidic water may release toxic concentrations of trace metals from the substrate which could make the water unfit for human consumption. Research is currently going on with this concern.

Monitoring the pH of Hedgehog should continue, but the groundwater underlying the park area should also be monitored. This would be a fine location for the USGS Geological Survey to conduct some of their upcoming seismic refraction and test drilling operations for groundwater next summer.

Hedgehog is shallow enough that no thermal stratification or oxygen depletion occurred. Oxygen levels were high enough to support fish life. It was too shallow to drop a secchi disk into the water.

The specific conductivity was also much lower than the average oligotrophic lake. It was 39 μmhos/cm @°25 C, which approaches the range of conductivity of some acid-killed lakes (16-24 μmhos/cm @°25 C).

Fecal coliform tests were taken often during the summer. One week showed a spurt of growth that peaked at 72 colonies/100 ml, but ten days later the count was back to 1 colony/100 ml. The maximum state limit is 240 colonies/100 ml.

MILLVILLE LAKE

There appears to be little change in the water quality at Millville Lake this year compared to the last ten years. The depth of critical oxygen depletion still occurred approximately 2.5 m (8 ft) below the surface. The secchi disk depth was still 2.0 m (6.6 ft) deep. The specific conductivity (147 μmhos/cm @ 25°C) and total alkalinity (16 mg $CaCO_3$/L) were both at average levels over the last ten years. However, these parameters still represent extremely enriched eutrophic conditions.

Profile measurements were taken on August 29 and September 15, and they showed a clearly defined thermocline just one foot above the lake bed. Oxygen depletion occurred at this depth. The lake bed was heavily vegetated, and this suggests nutrient loading in the lake.

The pH was 6.40, which is within normal pH range.

Millville's high alkalinity exceeds 90% of all other New Hampshire lakes and, coupled with its very high conductivity count, suggests a rapid rate of eutrophication is occurring here.

Fecal coliform bacteria counts were collected at the two deep sampling sites, plus at six shoreline locations during the summer. All were well below the state's maximum limit of 240 colonies/100 ml, ranging between 10-61 colonies/100 ml.

Slowing Millville's rate of eutrophication would be a difficult and expensive job. While there are many serious cultural eutrophication sources that demand attention, there are also important natural physical and hydrological factors that rush Millville's aging process. It has a watershed area : lake volume ratio five times larger than the next closest lake in town. Except for World End Pond, it has the shallowest mean depth, and it has many pocket sized shallow coves along its irregular shoreline which all further tends to increase the eutrophication rate of a lake.

Combatting the combined effects of both eutrophic factors - both natural and cultural - will mean regular water drawdowns and dredging operations every decade.

SHADOW LAKE

Surface and profile oxygen/temperature measurements were taken on Shadow Lake on July 29. After comparing this year's data with that of past years, there appears to be very little change in the water quality since 1976, though there may be some improvements.

The water was still stratified and, as in previous years, oxygen depletion still occurred below 3 m (10 ft). Its specific conductivity was still a too high 130 μmhos/cm @ 25°C. These are signs of cultural eutrophication, along with its all-too-visible densely populated shoreline.

However, Shadow Lake's total alkalinity is the only one of Salem's lakes to show a decrease since 1976 - from 9.5 down to 8.0 mg $CaCO_3$/L. As such, it is the only lake in town to approach the "normal" New Hampshire alkalinity value. This is significant because a lowering alkalinity could be a clue to decreasing eutrophication. The pH of Shadow also seems to be dropping to a more representative value, and may be responsible for a slightly deeper transparency. More data is needed to determine if these improving parameters represent a trend or if they reflect just normal variation.

One fecal coliform test was taken in the cove near Doiron Road. The result was 49 colonies/100 ml, which is a good count.

There are physical factors at work which discourages eutrophication at Shadow. Its watershed area : water volume is second only to Canobie Lake. It has the second greatest mean and maximum depth of any lake in town, again following Canobie Lake. It has the greatest average bottom slope of any lake in Salem. These factors all offset its comparitively small surface area to discourage eutrophication.

Shadow Lake could use a public right-of-way, even if it's only nothing more than a walkway to launch a small boat or canoe. It should also include a small parking lot nearby.

WILSON'S POND

Wilson's Pond was measured only once during the summer. Profile dissolved oxygen/temperature data were not taken, nor was a secchi disk measurement of water transparency taken.

The pH was 6.59 and the specific conductivity was 136 μmhos/cm. This latter measurement is high and could be due to its proximity to the Shannon Road landfill. Both measurements corresponded well with the data taken last year.

There were 23 colonies/100 ml of fecal coliform bacteria in the water during the late summer.

WORLD END POND

World End Pond was measured twice during the summer. It is the most naturally eutrophic pond in Salem and has good recreational value around its non-developed shore.

No thermal or oxygen stratification was observed during the summer. The oxygen content was high enough to support the needs of warm water fish.

The pH ranged from 6.22 to 6.66. The average pH of 6.52 was just a little lower than what was measured in 1984 and 1985, but still fell within the normal range of eutrophic lakes.

The total alkalinity was an extremely high 36 mg $CaCO_3$/L, but that is not an unusual figure for such eutrophic water bodies. It compared favorably with the result of the NH WSPCC lake studies taken two years ago when it was measured at 33.7 mg $CaCO_3$/L.

Secchi disk measurements were always seen resting on the weedy 1 m (3.3 ft) deep bottom.

The specific conductivity was a high 173 μmhos/cm @ 25°C.

Bacteria tests were taken twice during the summer, and both samples showed 0 colonies/ml.

World End Pond is a valuable wildlife refuge right at the doorstep of a densely urbanized section of town. Protecting the water quality here is critical to maintaining the fine aquatic ecology around World End Pond.

STREAMS

Twentythree stream sites were sampled during the course of the 1986 monitoring program. Nearly all of these sites were tested twice for fecal coliform bacteria, pH, dissolved oxygen, and specific conductivity. Their locations, date sampled, and the results of the parameters are included in Appendix II at the end of this report.

Last year's monitoring disclosed five of those sites as being particularly polluted by fecal coliform bacteria, and recommended that each be closely watched this year. Those sites, with their fecal coliform bacteria counts from both last year and this year, are shown in Table 5. Their locations are shown in Figure 5.

Four sites (5, 17, 18, and 21) showed improvements since last year, especially since the single high count at site 5 on June 31 (707 colonies/100 ml) could have been explained by a dead Great Blue Heron found a short distance upstream. Site 17, though it still sho ed an improvement from the year before, nonetheless had disturbingly high bacteria counts. This investigation was interrupted when a higher priority Mary Ann Beach bacterial contamination case began. Site 22 could not be sampled due to ongoing construction upstream which caused abnormally low and silty flows which would have yielded unrepresentative samples.

One additional stream site showed high bacterial contamination during the summer which required further investigation. The Arlington Reservoir inlet at Cowbell Corner (site 16) had high counts of coliform bacteria at locations both up and downstream of the normal testing location. (see Figure 6).

TABLE 5

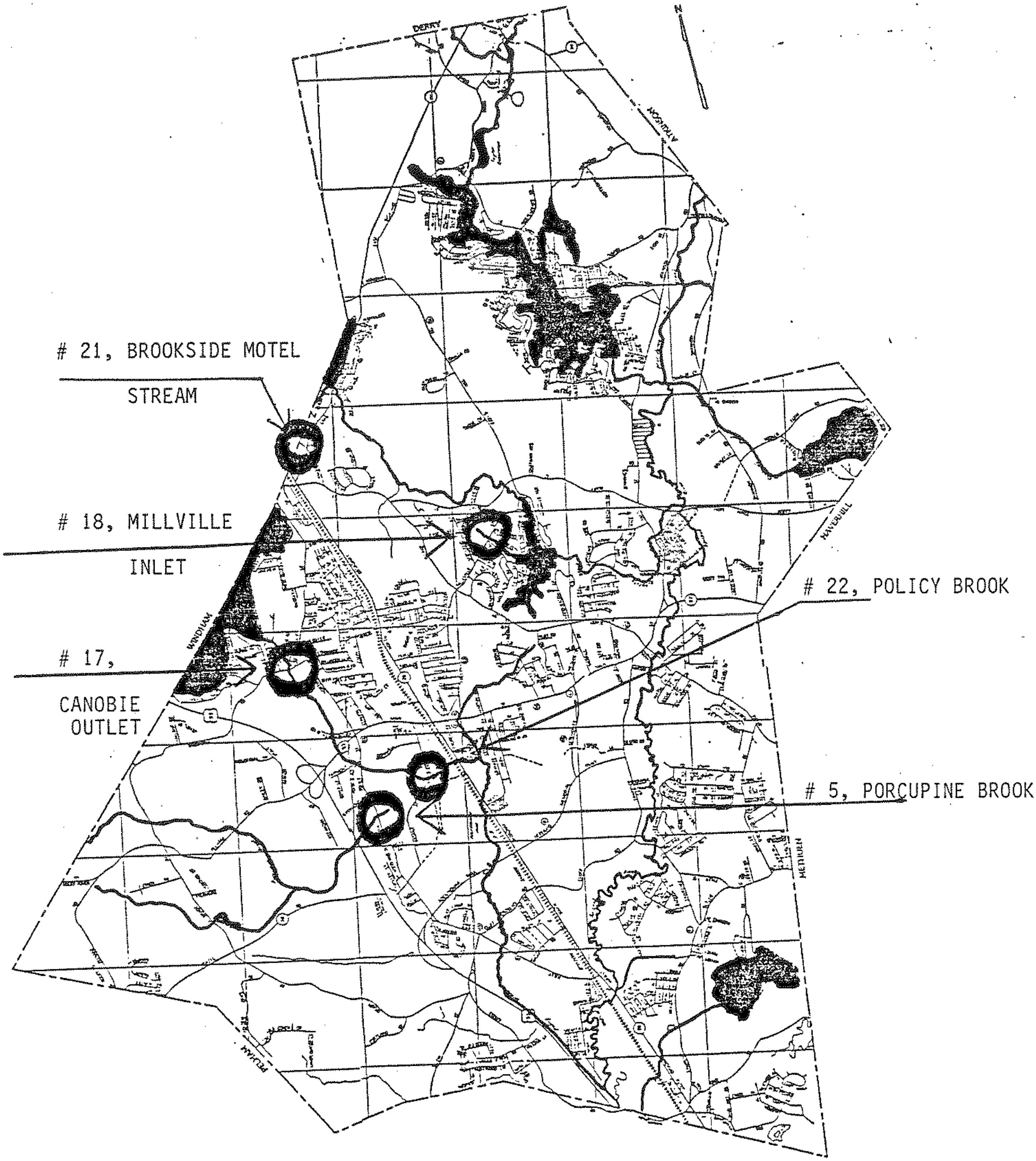
COMPARING UNSANITARY 1985 STREAM DATA WITH 1986 DATA

Site	Location	Fecal Coliform (colonies/100 ml) 1985 *		1986	
5	Porcupine Brook: (S. Policy St.)	TNTC	(6/20)	0	(7/24)
		550	(6/26)	707	(7/31)
		480	(7/17)	23	(9/11)
17	Canobie Lk. outlet:				
	(Brookdale Rd.)	140	(6/24)		
	(small trib. downstream of dam)	2750	(7/21)		
	(E. storm drain on Brookdale Rd.)			TNTC	(7/21)
	(W. storm drain on Brookdale Rd.)			131	(")
	(10 feet upstream)			152	(")
	(old culvert under Bus Rd.)			436	(")
	(below weir at Canobie Lk.)			59	(")
	(10 feet upstream)			235	(7/29)
	(20 feet upstream)			310	(")
18	Millville Inlet:				
	(Grove Ave.)	1800	(6/26)	25	(7/17)
	(upstream source)			70	(")
	(entry point into lake)			20	(")
21	Brookside Motel Stream:				
	(S. of Rt. 111)	235	(6/3)	477	(7/16)
	(")	312	(6/6)	91	(9/10)
	(drain pipe beside motel)	>2000	(")		
	(")	TNTC	(6/20)		
	(")	>5000	(7/2)		
	(")	40,000	(7/5)		
	(")	40,000	(7/29)		
	(inlet to pond)	326	(6/6)	93	(7/16)
	(")	720	(7/2)		
	(pond)			200	(7/16)
22	Policy Brook:			upstream construction caused low flows and unrepresentative samples this year	
	(Pleasant St.)	720	(6/24)		
	(")	TNTC	(7/9)		
	(")	TNTC	(7/11)		

* 1985 samples performed by Dan Dudley
TNTC: Too Numerous Too Count

FIGURE 5

LOCATION KEY : 1985 UNSANITARY STREAM SITES



Fecal streptoccocus tests were performed on September 29 at these locations in an attempt to identify the source of this contamination. The results, which may be somewhat questionable, showed both animal and human sources.

These results may be inaccurate because of the limitations of the fecal streptoccocus test. It requires a companion fecal coliform test to be taken the same day and at the same site, and it must have a count of at least 100 colonies/100 ml. Next, the result of a fecal coliform to fecal streptoccocus ratio (FC/FS) would be compared to known fecal pollution sources to determine the origin of a given contaminated site.

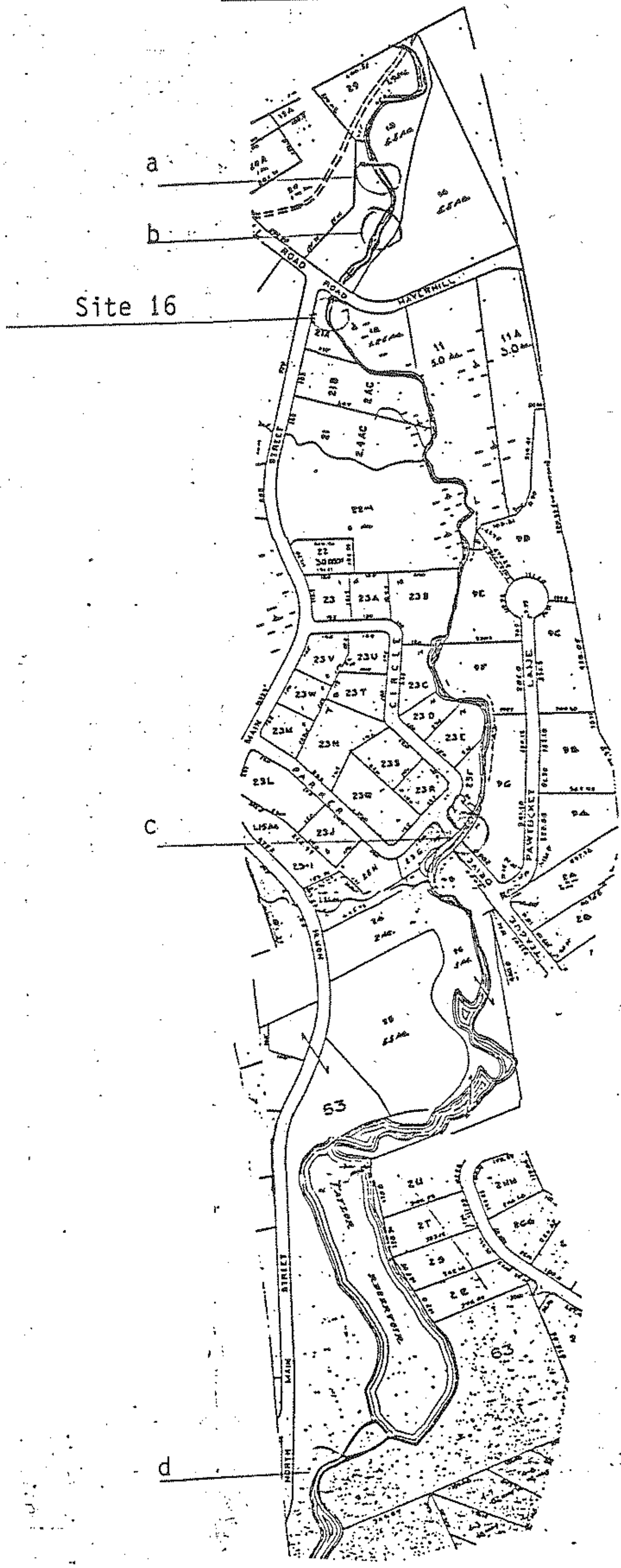
Most of the companion fecal coliform tests performed at Cowbell Corner did not reach the required count, and the only one that did just barely made it. Thus, the aforementioned conclusion is of a questionable nature.

Cowbell Corner is an agricultural area of town and many farm-yards abut the stream. Cows, horses, and poultry are common here and wildlife such as mink and ducks inhabit the less-developed upstream reaches. Keeping livestock away from the stream would be the best way to keep the stream sanitary, but it is nonetheless a very difficult task to do. The New Hampshire Water Supply and Pollution Control Commission and the Rockingham County Soil Conservation Service are both aware of the magnitude of this problem throughout the region and have a low key approach to it.

The possible human source could not be determined because of the increased stream flow from the release of water at the upstream Island Pond dam on October 1 which would have diluted the bacterial count.

FIGURE 6

LOCATION KEY : COWBELL CORNER SITES & RESULTS



DATE	SITE	Fecal Coliform (colonies/100 ml)
8/15	16	-
9/ 9	16	475
9/11	16	542
	b	339
9/17	a	68
	b	24
	c	231
	d	41
9/25	a	400
	b	error
	16	370
	c	250 (above storm drain)
	c	233 (below storm drain)
	d	509
9/29	a	0
	b	0
	16	156
	c	94
	d	43

APPENDICES

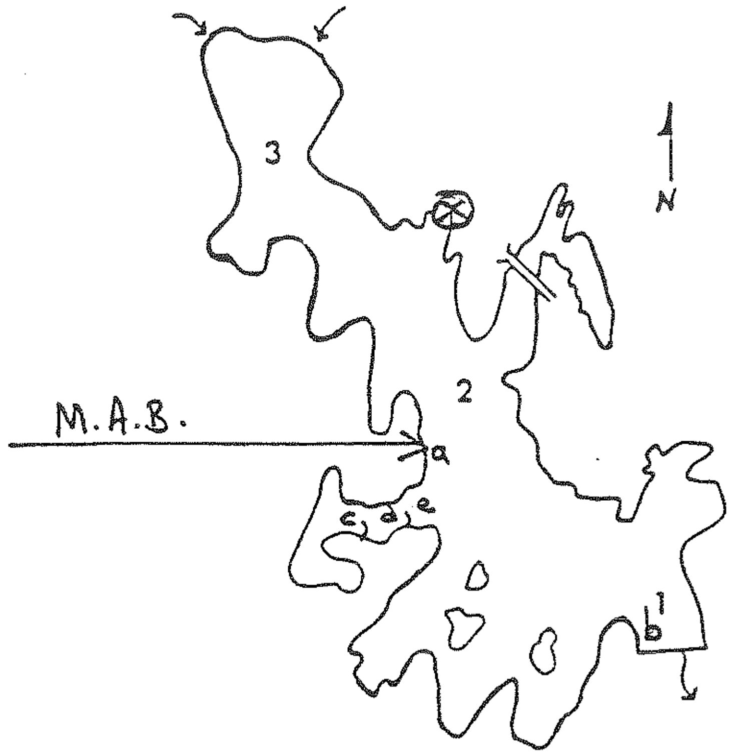
APPENDIX I

LAKE DATA & MAPS

Lake	Date	Site	Depth [m]	Secchi Disk [m]	Dissolved oxygen [mg/L]	Temp. [°C]	Total Alkalinity [mg $CaCO_3$/L]	pH	Specific Cond. [µmhos/cm]
ARLINGTON	19 Jul	1	S	4.1	-	-	12	6.29	112
		2	S	3.3	12.0	21	12	6.54	115
			1.0		11.8	21			
		3	S	3.2	12.2	22	14	6.53	115
			1.0		11.7	20			
	26 Aug	1	S	3.8	6.66	23.0		6.28	105
			1		6.43	22.8			
			2		6.70	22.2			
			3		7.09	21.8			
			4		6.20	21.7			
			5		5.94	21.6			
			6		6.15	21.4			
			7		0.18	19.0			
			8		0.05	17.1			
			9		0.02	16.5			
			10		0.02	15.3			
			10.7		0.02	13.7		6.06	
		2	S	3.6	6.91	22.8		6.34	105
			1		6.85	22.7			
			2		6.57	21.7			
			3		6.55	21.6			
			4		6.50	21.5			
			5		6.15	21.3			
			5.3		5.50	21.2			
			5.7		1.51	20.4			
			6.0		0.02	19.5			
			6.3		0.04	18.4			

Lake	Date	Site	Depth [m]	Secchi Disk [m]	Dissolved oxygen [mg/L]	Temp. [°C]	Total Alkalinity [mg $CaCO_3$/L]	pH	Specific Cond. [µmhos/cm]
ARLINGTON	26 Aug	3	S	1.9	6.50	23.2		6.28	108
			1		6.41	22.8			
			2		6.20	22.0			
			3		6.03	21.4			
			3.5		5.54	21.3		6.18	
	15 Sep	1	S	2.6	7.93	19.4		6.34	112
			1		7.88	19.4			
			2		7.89	19.4			
			3		7.60	19.2			
			4		7.32	19.1			
			5		7.25	19.1			
			6		6.49	19.1			
			7		5.05	18.8			
			7.5		3.51	18.6			
			8		0.44	17.8			
			9		0.11	16.0			
			10		0.13	13.6			
		3	S	2.5	10.50	13.6		6.34	115
			1		7.70	19.0			
			2		7.70	19.0			
			3		7.79	18.9			
			4		7.01	18.8			
			5		7.37	18.7			
			5.7		6.19	18.7			

ARLINGTON RESERVOIR



⊗: Access site (Dockside Marina, 321 N. Main St.)

M.A.B. : Mary Ann Beach

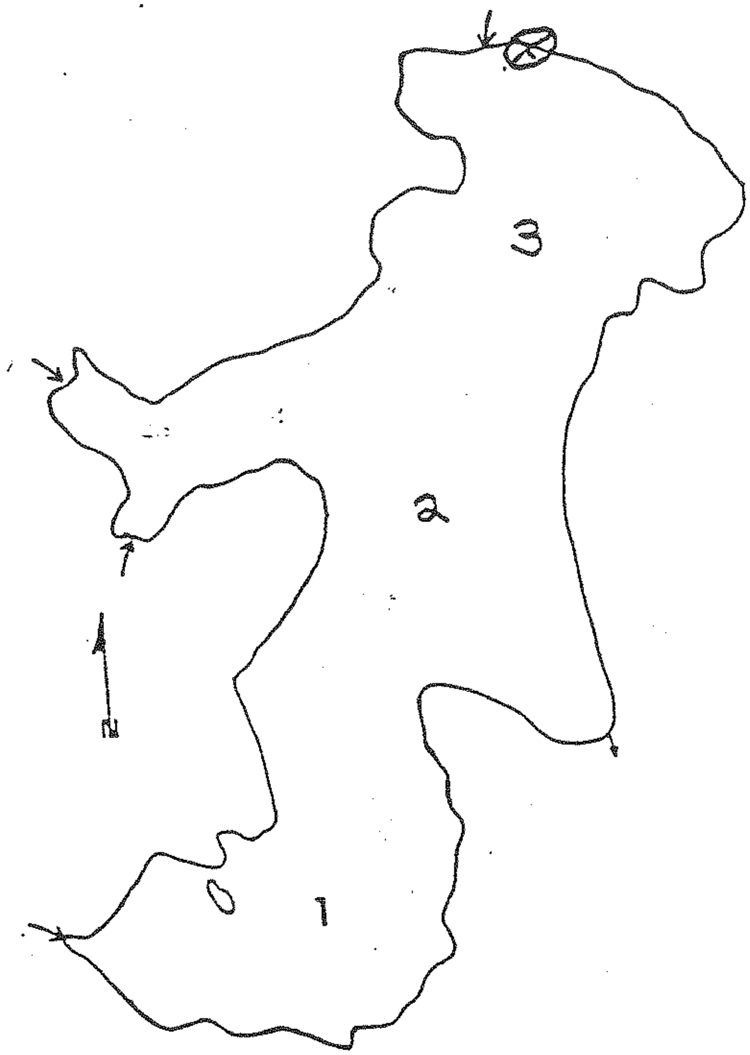
FECAL COLIFORM SITES AND RESULTS

Date	Location	Key	Colonies/100 ml
19 Jul	site 1	1	0
	site 2	2	4
	site 3	3	2
5 Aug	lot #27, Cove Rd.	a	11
14 Aug	43 Wheeler Dam Rd.	b	3
28 Aug	1 Graham Ave.	c	6
	3 Graham Ave.	d	35
	5 Graham Ave.	e	9

Lake	Date	Site	Depth [m]	Secchi Disk [m]	Dissolved oxygen [mg/L]	Temp. [°C]	Total Alkalinity [mg $CaCO_3$/L]	pH	Specific Cond. [µmhos/cm]
CANOBIE	29 Aug	1	S	*	8.51	20.9		6.49	137
			1		8.39	20.9			
			2		8.32	20.8			
			3		8.29	20.7			
			4		8.32	20.6			
			5		8.24	20.4			
			6		8.08	20.3			
			7		7.95	20.2			
		2	S	*	8.67	20.8		6.60	137
			1		8.37	20.8			
			2		8.36	20.8			
			3		8.28	20.8			
			4		8.28	20.8			
			5		8.21	20.7			
			6		8.17	20.7			
			7		7.79	20.3			
			7.5		6.95	20.1			
			8.0		6.06	19.4			
			8.3		4.75	18.9			
		3	S	*	8.30	20.8		6.42	137
			1		8.23	20.8			
			2		8.18	20.8			
			3		8.12	20.8			
			4		7.75	20.7			

* : Secchi Disk not taken ... current too strong

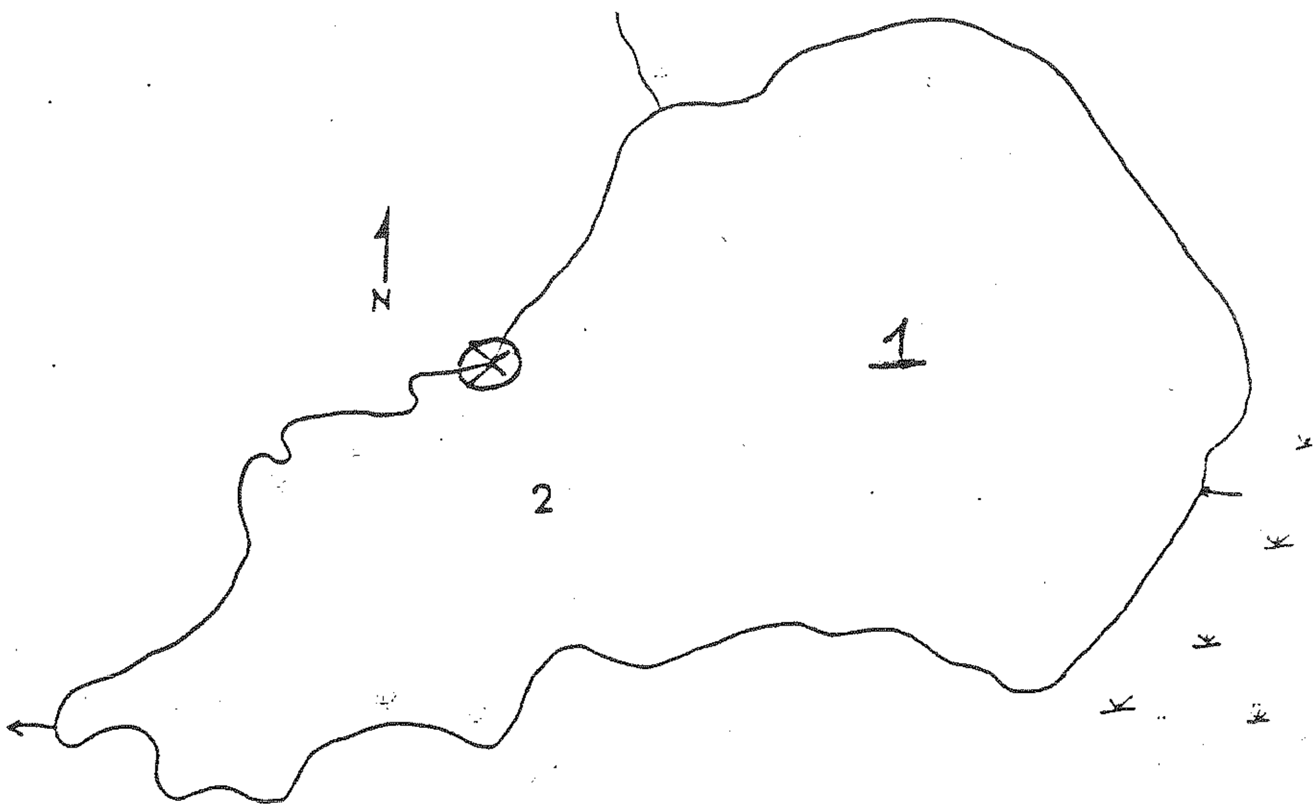
CANOBIE LAKE



⊗ : Access Point

Lake	Date	Site	Depth [m]	Secchi Disk [m]	Dissolved oxygen [mg/L]	Temp. [°C]	Total Alkalinity [mg $CaCO_3$/L]	pH	Specific Cond. [µmhos/cm]
CAPTAINS	13 Aug	1	S	3.0	11.5	26	11	6.75	86
			1		11.0	23			
		2	S	3.0	11.4	25	11	6.85	82
			1		11.1	22			
	5 Sep	1	S	3.6	7.60	19.2		6.64	78
			1		7.78	19.2			
			1.5		6.96	19.0			
			2.0		6.50	18.9			
			2.5		6.35	18.7			
			3.0		7.05	18.6			
			3.5		7.01	18.5			
			4.0		6.45	18.4			
			4.5		5.05	18.1			
			5.0		1.81	16.2			
			5.5		0.16	14.2			
			6.0		0.16	13.2			
			6.5		0.06	12.5			
			7.0		0.06	12.1			
			7.5		0.03	11.9			

CAPTAINS POND



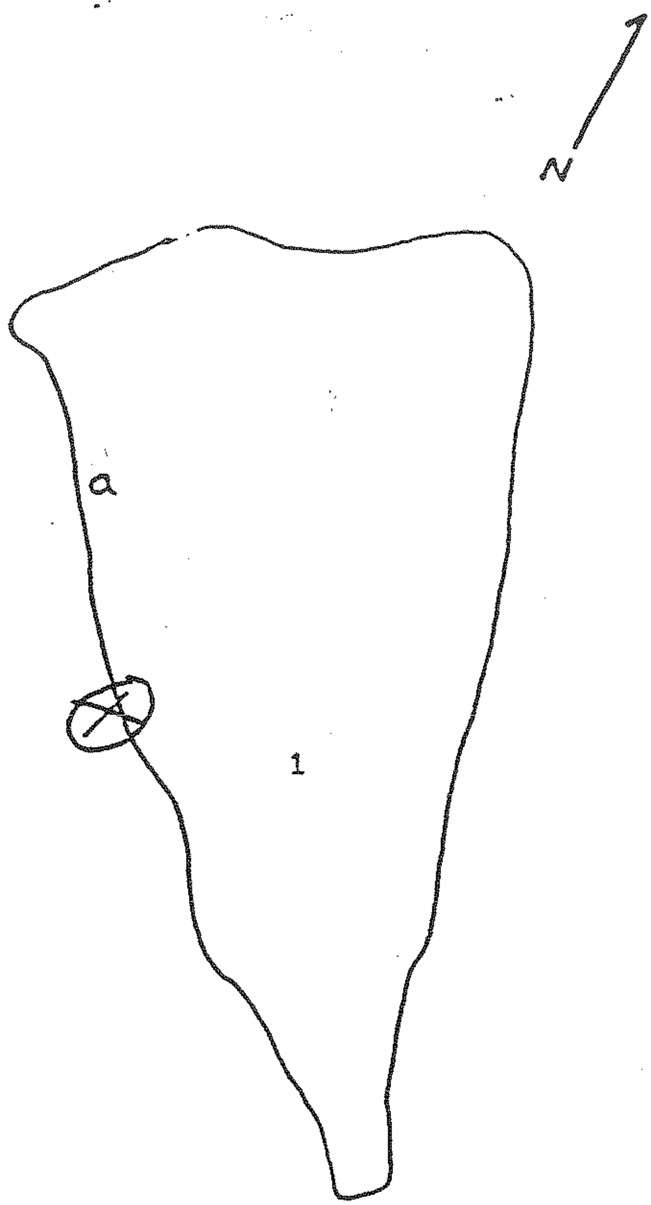
⊗ : Access Point

FECAL COLIFORM SITES AND RESULTS

Date	Location	Key	Colonies/100 ml
13 Aug	site 1	1	0
	site 2	2	2
5 Sep	site 1	1	0

Lake	Date	Site	Depth [m]	Secchi Disk [m]	Dissolved oxygen [mg/L]	Temp. [°C]	Total Alkalinity [mg $CaCO_3$/L]	pH	Specific Cond. [µmhos/cm]
HEDGEHOG	14 Jul	1	S	VOB					
	21 Jul	1	S	VOB	12.4	25	0	5.06	40
	31 Jul	1	S	VOB	12.5	22	1.0	4.95	41
			1		12.3	22			
	11 Aug	1	S	VOB				6.55	
	4 Sep	1	S	VOB	12.3	18	0	5.65	36

HEDGEHOG POND



⊗ : Access Point (Swimming beach at Hedgehog Park)

FECAL COLIFORM SITES AND RESULTS

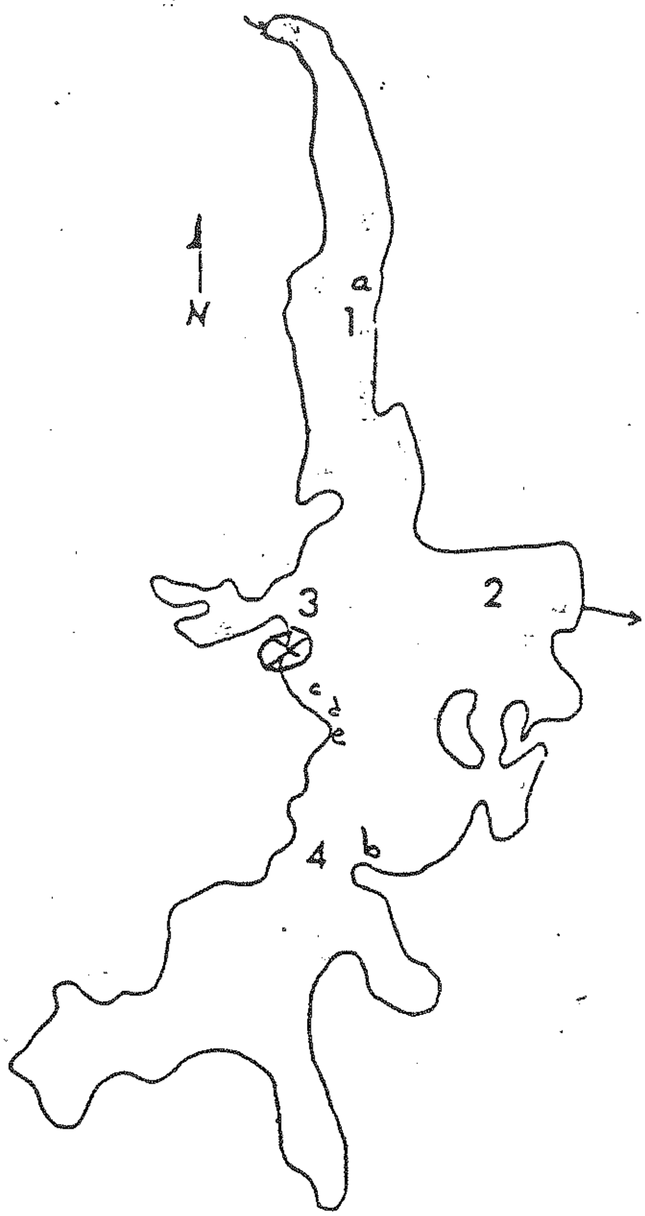
Date	Location	Key	Colonies/100 ml
14 Jul	site 1	1	0
21 Jul	site 1	1	17
31 Jul	site 1	1	72
	just N. of beach	a	62
11 Aug	site 1	1	1
4 Sep	site 1	1	1

Lake	Date	Site	Depth [m]	Secchi Disk [m]	Dissolved oxygen [mg/L]	Temp. [°C]	Total Alkalinity [mg $CaCO_3$/L]	pH	Specific Cond. [µmhos/cm]
MILLVILLE	9 Jul	3	S		11.1	25			
			1		2.8	15			
	22 Jul	1	S	1.7	12.5	25	15	6.73	155
			1		0.6	16			
		2	S	1.7	12.0	25	16	6.99	150
			1		2.2	16			
	29 Aug	1	S	2.0	7.39	20.4		6.39	114
			0.5		7.10	20.0			
			1.0		7.02	19.8			
			1.5		6.78	19.6			
			2.0		6.73	19.5			
			2.3		5.87	18.9			
		2	S	2.0	7.14	20.5		6.26	149
			0.5		7.11	20.5			
			1.0		7.03	20.2			
			1.5		6.80	19.8			
			2.0		6.41	19.5			
			2.5		0.46	18.3			
			3.0		0.31	18.3			
			3.2		0.13	17.5			
		4	S	1.9	7.79	20.4		6.08	145
			0.5		7.60	20.5			
			1.0		7.49	20.4			
			1.5		7.46	20.3			
			2.0		7.41	20.1			
			2.5		7.37	19.9			
			3.0		6.02	19.4			
			3.3		0.16	16.7			

(continued)

Lake	Date	Site	Depth [m]	Secchi Disk [m]	Dissolved oxygen [mg/L]	Temp. [°C]	Total Alkalinity [mg $CaCO_3$/L]	pH	Specific Cond. [μmhos/cm]
MILLVILLE	15 Sep	1	S	VOB	8.12	19.6		6.46	157
			0.5		8.02	19.6			
			1.0		7.71	19.1			
			1.5		7.52	18.9			
			2.0		7.18	18.5			
		2	S	2.6	8.30	19.2		6.48	158
			0.5		8.10	19.3			
			1.0		8.10	19.3			
			1.5		8.03	19.3			
			2.0		8.08	19.2			
			2.5		7.93	19.2			
			3.0		7.19	18.4			
			3.5		6.84	18.1			
			3.8		5.67	18.0			

MILLVILLE LAKE



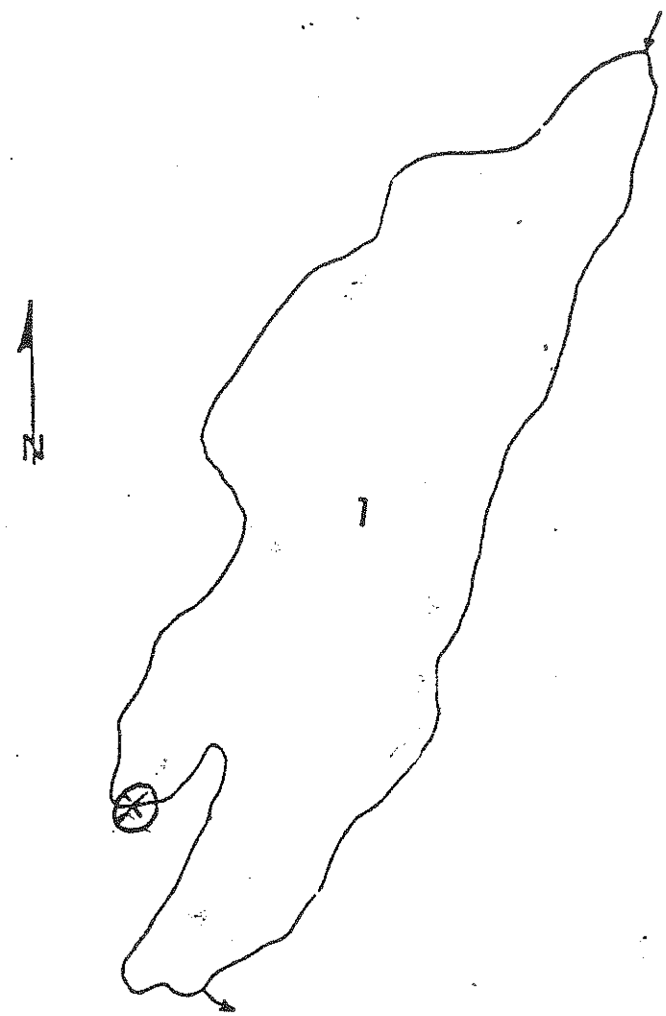
⊗ : Access Point (35 Grove Ave)

FECAL COLIFORM SITES AND RESULTS

Date	Location	Key	Colonies/100 ml
9 Jul	site 3	3	30
22 Jul	site 1	1	61
	site 2	2	18
	Town beach	a	10
14 Aug	Woodmeadow Dr. Beach	b	11
25 Aug	39 Grove Ave.	c	15
	41 Grove Ave.	d	51
	43 Grove Ave.	e	19

Lake	Date	Site	Depth [m]	Secchi Disk [m]	Dissolved oxygen [mg/L]	Temp. [°C]	Total Alkalinity [mg $CaCO_3$/L]	pH	Specific Cond. [μmhos/cm]
SHADOW	9 Jul	1	S		11.0	24	8.0		
			1.0		5.7	16			
	16 Jul	1	S		10.8	22			
	29 Jul	1	S	2.8	8.25	20.8		6.29	136
			1.0		7.92	20.3			
			2.0		7.57	19.7			
			2.5		7.20	19.6			
			3.0		3.60	18.9			
			3.5		0.85	15.8			
			4.0		0.16	13.7			
			4.5		0.06	12.2			
			5.0		0.06	10.5			
			5.5		0.04	9.8			
			6.0		0.04	9.4			
			6.5		0.04	9.0			

SHADOW LAKE



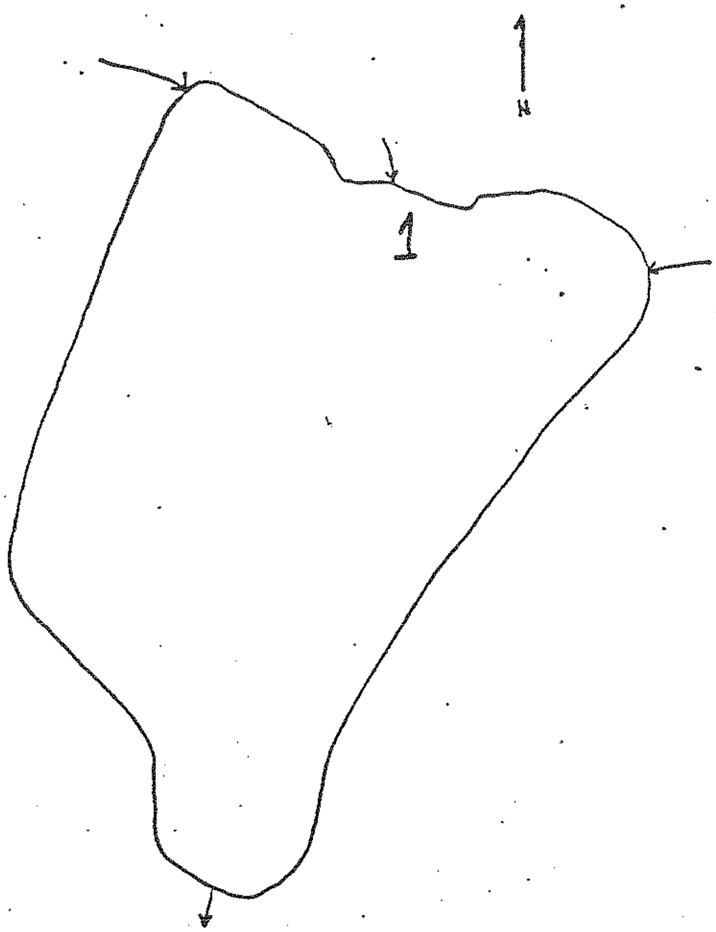
 : Access Point

FECAL COLIFORM SITES AND RESULTS

Date	Location	Key	Colonies/100 ml
16 Jul	Site 1	1	49

Lake	Date	Site	Depth [m]	Secchi Disk [m]	Dissolved oxygen [mg/L]	Temp. [°C]	Total Alkalinity [mg $CaCO_3$/L]	pH	Specific Cond. [µmhos/cm]
WILSON'S	21 Aug	1	S					6.59	136
WORLD END	22 Jul	1	S	1.1	11.3	24	36	6.66	177
			1		0.4	19			
	5 Sep	1	S	VOB	6.80	18.9		6.22	169
			0.5		6.32	18.4			
			1.0		6.44	17.8			

WILSON'S POND

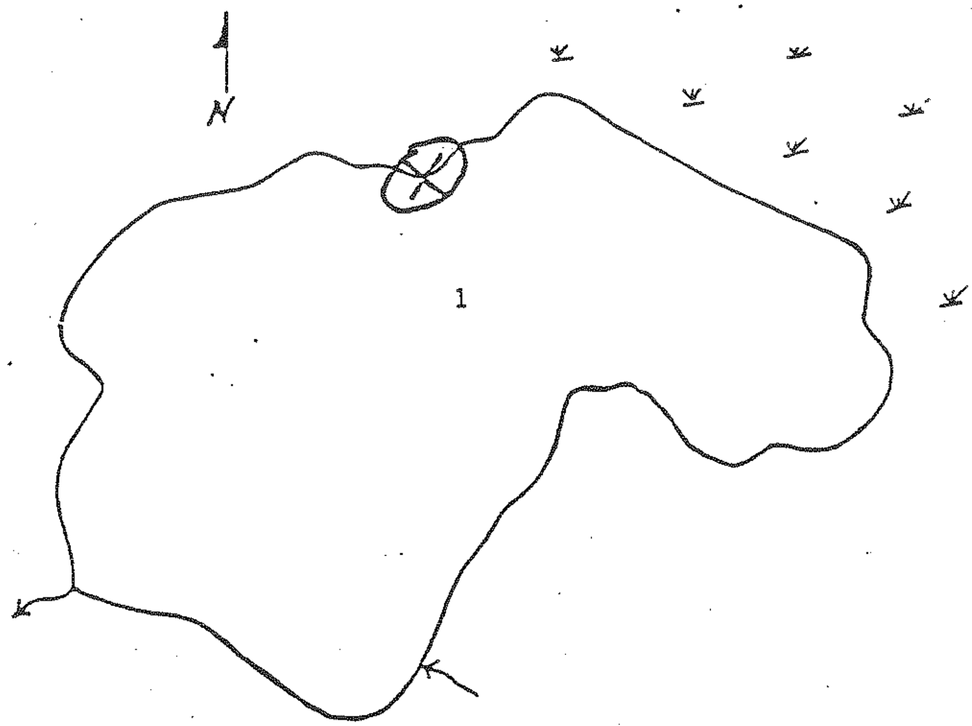


: Access Point

FECAL COLIFORM SITES AND RESULTS

Date	Location	Key	Colonies/100 ml
21 Aug	Middle inlet	1	23

WORLD END POND



⊗ : Access Point

FECAL COLIFORM SITES AND RESULTS

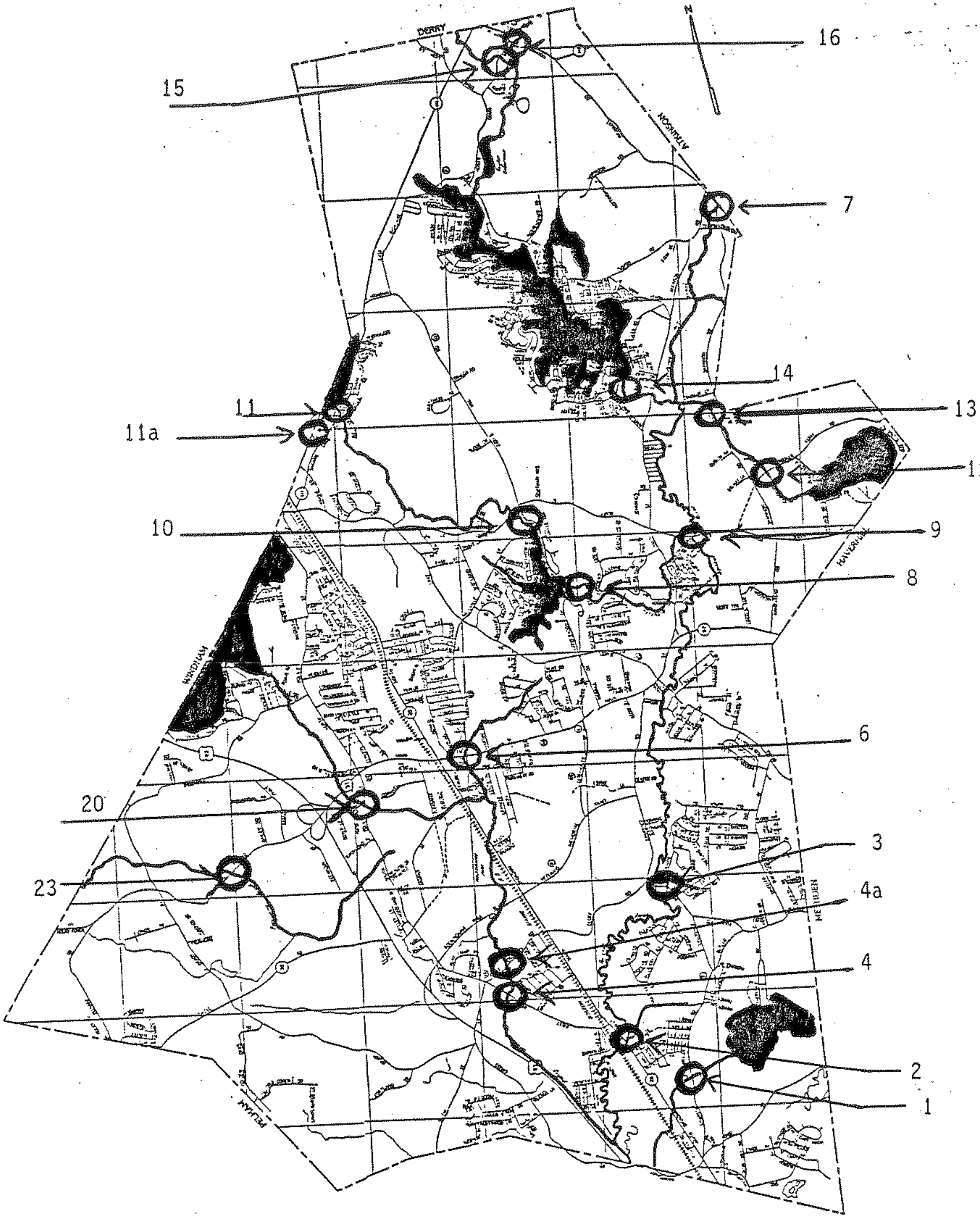
Date	Location	Key	Colonies/100 ml.
22 Jul	site 1	1	0
5 Sep	site 1	1	0

APPENDIX II

STREAM DATA

FIGURE II-7

LOCATION KEY : 1986 STREAM SITES *



* : Not including those sites keyed in Figure 5

APPENDIX II

STREAM DATA

Site #	Location	Date	pH	D.O. [mg/L]	Spec. Cond. [μmhos/cm @ 25°C]	Fecal Coliform [colonies/100 ml]
1	World End Brook (Lawrence Road)	9/9	6.60	5.1	200	0
2	Spickett River (Rt. 28)	8/15	6.63	10.2	166	-
		9/9	6.84	10.5	168	0
3	Spickett River (Lawrence Road)	8/15	6.59	10.4	159	-
		9/9	6.76	11.4	163	29
4	Policy Brook (Kelly Road)	7/30	6.77	9.3	330	error
		9/11	6.96	-	-	-
4a	Policy Brook (Cluff Crossing)	7/30	6.78	7.5	325	error
		9/11	6.71	7.5	450	0
5	Porcupine Brook (S. Policy Street)	7/24	-	-	-	0
		7/31	6.46	12.0	355	707
		9/11	6.90	13.0	450	23
6	Policy Brook (Main Street)	7/29	6.81	9.6	260	44
7	Spickett River (Haverhill Rd)	8/15	6.55	10.6	138	-
		9/9	6.74	10.4	119	0
8	Millville Outlet	9/10	6.53	3.5	200	0
9	Spickett River (Town Farm Rd.)	8/15	6.53	12.2	150	-
		9/9	6.75	10.9	140	24
10	Millville Inlet (Millville St.)	7/9	-	9.5	-	28
		9/10	6.53	9.6	190	50
11	Shadow Lake Outlet (Rt. 111)	7/9	-	10.3	-	50
		9/10	6.88	9.4	153	19

Site #	Location	Date	pH	D.O. [mg/L]	Spec. Conductivity [μmhos/cm @ 25°C]	Fecal Coliform [colonies/100 ml]
11a	Shadow Lake Inlet (Doiron Rd.)	7/16	-	-	-	57
		9/10	6.79	10.6	240	74
12	Captains Pond Brk. (Hooker Farm Rd.)	8/18	6.38	7.4	87	-
		9/9	6.63	10.4	76	61
13	Captains Pond Brk. (Shannon Rd.)	8/18	6.38	-	-	-
		9/19	6.63	11.4	83	0
14	Arlington Res. Outlet	8/18	6.53	12.5	126	-
		9/19	6.91	12.7	123	0
15	Arlington Res. Inlet (N. Main St.)	8/15	6.40	4.5	240	-
		9/9	6.73	9.6	220	33
16	Arlington Res. Inlet (Cowbell Corner bridge)	8/15	6.56	11.2	110	-
		9/9	6.93	13.5	104	475
	(pool upstream of Bridge)	9/11	-	-	-	339
	(Cowbell Corner bridge)		-	-	-	542
	(dam at Island Pond)	9/17	-	-	-	1
	(Rt. 111)		-	-	-	0
	(100 yards N. of pool upstream of bridge)		-	-	-	68
	(pool upstream of bridge)		-	-	-	24
	(Teague Drive bridge)		-	-	-	231
	(Taylor Reservoir Outlet)		-	-	-	41
	(100 yards N. of pool upstream of bridge)	9/25	-	-	-	400
	(pool upstream of bridge)		-	-	-	error
	(Cowbell Corner bridge)		-	-	-	370
	(above storm drain, Teague Drive bridge)		-	-	-	250
	(below storm drain, Teague Drive bridge)		-	-	-	233
	(Taylor Reservoir Outlet)		-	-	-	509

Site #	Location	Date	pH	D.O. [mg/L]	Spec. Conductivity [μmhos/cm @ 25°C]	Fecal Coliform [colonies/100 ml.]
16	Arlington Res. Inlet					
	(100 yards N. of pool upstream of bridge)	9/29	-	-	-	0 (105)*
	(pool upstream of bridge)		-	-	-	0 (133)
	(Cowbell Corner bridge)		-	-	-	156 (122)
	(Teague Drive bridge)		-	-	-	94 (68)
	(Taylor Reservoir outlet)		-	-	-	43 (10)
17	Canobie Lake outlet stream:					
	(E. storm drain, Brookdale Road)	7/21	-	-	-	TNTC
	(W. storm drain, Brookdale Road)		-	-	-	131
	(10 ft.above Brookdale Rd)		-	-	-	152
	(old culvert, Bus Rd)		-	-	-	436
	(weir @ Canobie outlet)		-	-	-	59
	(10 ft above Brookdale Rd)	7/29	-	-	-	235
	(20 ft above Brookdale Rd)		-	-	-	310
18	Millville inlet, Grove Ave:					
	(culvery @ furthest point upstream)	7/17	-	-	-	70
	(culvert, Millville St)		-	-	-	25
	(entry pt. to lake)		-	-	-	20
20	Policy Brook (Point "A" Rd)	7/17	-	-	-	too silty
21	Brookside Motel:					
	(upstream of motel)	7/16	-	-	-	93
	(lower pond)		-	-	-	200
	(S. of Rt 111)		-	-	-	477
	(S. of Rt 111)	9/10	-	-	-	91
22	Policy Brook, Pleasant St	7/17	-	-	-	too silty

* : Fecal Streptoccocus test results [colonies/100 ml.]

TNTC : Too Numerous Too Count

APPENDIX III

THE pH OF RAINFALL OVER CONCORD, NH; May to October 1986 *

Date		pH
May	5	4.05
	6- 9	3.72
	21	4.27
	26	4.35
	28	3.94
Jun	1- 2	4.10
	5- 6	3.88
	11-13	4.18
	16 (AM)	3.99
	16 (PM)	3.94
	20	4.49
	30	4.13
Jul	2	4.72
	5- 6	3.86
	12-13	4.10
	14	4.31
	26-27	3.88
	29	3.79
	30	4.09
Aug	8	3.89
	9-10	3.81
	16-17	4.00
	27	3.84
Sep	5- 6	3.97
	15-16	3.77
	20-21	3.87
	23	4.14
	29	3.45

Average rainfall pH from May to October --- 3.95
normal pH of rainfall --- 5.60

* : Data taken from NH WSPCC rain gauge on NH Health & Welfare building rooftop, Hazen Drive, Concord, NH.